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ECOLOGY OF THE MURRAY ISLAND CORAL REEF

By Alfred G. Mayer

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By

Alfred Goldsborough Mayer

Director of the Department of Marine Biology of the Carnegie Institution of Washington

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ECOLOGY OF THE MURRAY ISLAND CORAL REEF.

By Alfred Goldsborough Mayer.

INTRODUCTION.[1]

It is a pleasure to speak of the generous interest which the officers of the Australian Commonwealth displayed in behalf of our expedition and without which its aims could not have been achieved. In response to the request of the president of the Carnegie Institution of Washington, the Right Honorable Viscount Bryce, then British ambassador to the United States, provided the director of the expedition with letters of introduction to their Excellencies the Governors of the Commonwealth of Australia and of Queensland.

Acting upon the advice of His Excellency Sir William Macgregor, M. D., G. C. M. G., C. B., governor of Queensland, the chief secretary of Queensland the Honorable D. Denham, and the chief under secretary the Honorable P. J. McDermott, I. S. O., recommended us to W. M. Lee-Bryce, esq., resident and magistrate at Thursday Island, who permitted us to make use of the court house and the jail on Murray Island for laboratory purposes, thus providing excellent quarters in which to conduct our biological studies.

Moreover, His Excellency J. H. P. Murray, M. A., C. M. G., lieutenant governor and chief judicial officer of Papua, in response to a letter of introduction from Judge Allan W. Macnaughton, kindly invited us to be his guests at Government House during the entire time of our visit to Port Moresby, New Guinea, and placed at our service the government launch and whale-boat.

To other friends our acknowledgments of aid and expressions of gratitude are also due: To R. Etheridge, esq., curator of the Australian Museum, Sydney; to Charles Hedley, esq., F. L. S., and to John Stewart Bruce, J. P., honorary fellow of the Anthropological Society of London and government teacher and magistrate of the Murray Islands, we are indebted for kind and active interest in our behalf and for advice which was of much importance in determining the success of the expedition.

We were also most kindly entertained upon Darnley Island by Thomas Arnold Williams, esq., and on Badu Island by Rev. F. W. Walker, the representative of a philanthropic association whose attempt to develop money-making arts and trades among the natives and to provide a market for their wares is of the highest interest, tending, as such efforts must, to develop in the aborigines a sense of self-dependence and to stimulate in them that ambition which is the key-note to the introduction of actual civilization among an erstwhile savage race.

[1]A narrative of the expedition was published in *Popular Science Monthly*, vol. 85, Sept. 1914; and an abstract of the results of the ecological study of the reef appeared in Proceedings of the National Academy of Sciences, vol. 1, pp. 211–214, 1915.

Finally, but by no means least in our appreciation, we may mention the kindness of Messrs. J. B. Arthur and R. A. C. Hockings of Thursday Island, who granted the use of their power-schooner *Kestrel* to transport five members of our expedition from Thursday Island to Darnley Island. Mr. Clark, manager of Hodel's Limited at Thursday Island, was also most kind upon many occasions.

Illness having prevented Dr. Thomas Wayland Vaughan from accompanying the expedition to Australia, it fell to the lot of the present writer to conduct these ecological studies. It is a pleasure to state that the notable work which Dr. Vaughan has already achieved in Florida inspired the author at every turn, but it would be unfair to hold Dr. Vaughan in any sense responsible for errors which may be detected in the present paper or for any opinions which may be expressed. Dr. Vaughan has kindly made a study of the specimens of corals collected at the Murray Islands and sent to him at Washington and has furnished the names of the set of numbered corals illustrated by plates 12 to 19, and has listed the preserved specimens on which experiments were made. He has read the proof of this paper and verified the names used, and made many valuable suggestions. An extensive systematic paper by him follows the present one in this volume.

It is with pleasure that the author acknowledges his indebtedness to Doctors T. Wayland Vaughan, John Johnston, and H. E. Merwin for important corrections and additions.

MAËR ISLAND AND ITS REEFS.

The Murray Islands lie in 144° 2′ E. Long., 9° 55′ S. Lat., thus being at the inner end of the Flinders Entrance and about 6 miles west of the seaward edge and near the northern end of the Great Barrier Reef of Queensland. Their nearest neighbors are Darnley Island, 25 miles, and Daru, New Guinea, about 70 miles to the northwest. Three volcanic islets, Maër,

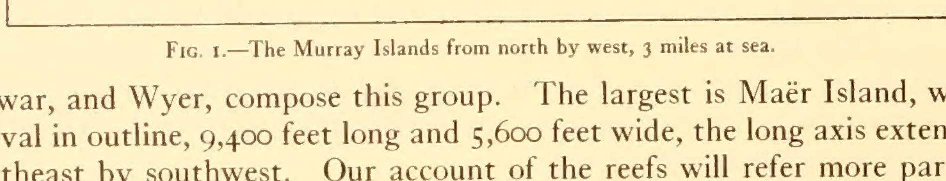

FIG. 1.—The Murray Islands from north by west, 3 miles at sea.

Dowar, and Wyer, compose this group. The largest is Maër Island, which is oval in outline, 9,400 feet long and 5,600 feet wide, the long axis extending northeast by southwest. Our account of the reefs will refer more particularly to those of this island. Its southwestern half consists of a crater rim of volcanic ash, which contains fragments of indurated, dolomitized limestone, indicating that it burst through ancient calcareous deposits. On the south-

western side this crater rim rises to a height of about 750 feet, but on the southeastern side it is only about 250 feet high. Hedley believes that the greater height of the westerly part of the crater rim is due to the southeast trade winds, which for about eight months in the year blow steadily across the island and would thus drift any ejected dust and ashes in a northwesterly direction. F. A. Potts, however, doubts the sufficiency of this simple explanation and presents evidence tending to show that the peculiar shape of the crater rim may be the result of one or more explosions. Within this chief crater of the island, situated somewhat eccentrically near the southeast side, there is a smaller and more recent ash-crater, at present consisting of two conical hills, the highest of which rises about 400 feet above sea-level and 250 feet above the floor of the great crater.

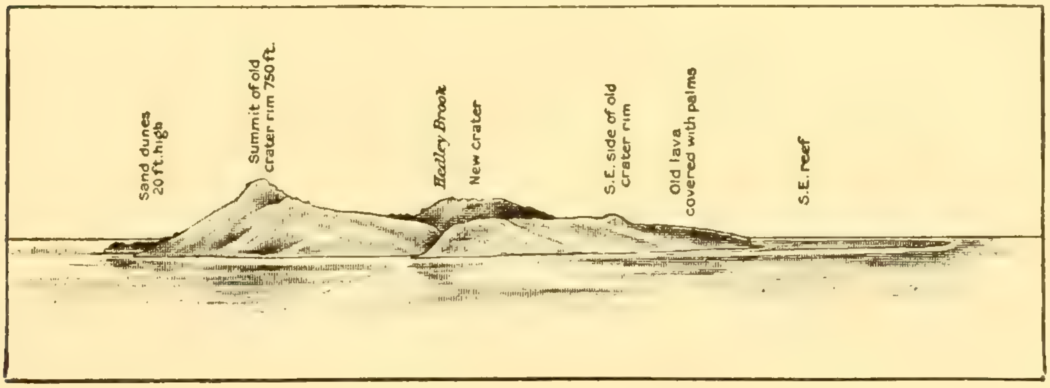

Fig. 2.—View of Maër Island looking northward from the summit of Wyer Island. Traced from a photograph taken by A. G. Mayer.

An extensive flow of lava proceeded from this smaller crater and broke through the northeast side, forming a large, oval, tongue-shaped projection which constitutes the northeasterly half of the island and is now covered with a dense growth of cocoanuts and other trees. (See plate 3 B.) Indeed, one may readily distinguish at a distance between the regions of ash-deposits and lava-flow, the former being almost barren save for a tangle of coarse grass and the lava being thickly covered with palms and other trees. Moreover, the decomposed ash is dull gray-brown and the lava rich reddish-brown.

Three streams, which flow only during the rainy season, have cut deep ravines into the slopes of the island. The largest of these we call Bruce Brook, in honor of John Bruce, esq., the well-known anthropologist, who as teacher and resident magistrate of the island has for more than twenty years labored to improve the condition of the natives. Bruce Brook flows out from near the center of the principal crater in a general northeasterly direction, making its way first over the floor of the crater and lower down over the region between the ash-rim and the lava-flow, cutting deeply into the underlying ash and forming cascades over the superficial lava. Another water-course, which we call Hedley Brook, in honor of Charles Hedley, well

known for his studies upon the biology of the Barrier Reef, flows southward with about three tributaries and has cut a deep ravine through a cleft in the southern side of the ash-rim of the crater. There is still another stream, which we name Haddon Brook, in honor of Dr. A. C. Haddon, of Cambridge University, by whose intensive anthropological studies in the Murray Islands the natives of this region are better known than are those of any other part of Torres Straits. Haddon Brook rises on the easterly side of the central cone and flows in a general southeasterly direction, cutting its way in a deep cañon through the volcanic ash.

Lieutenant Frank A. Potts, of our expedition, paid special attention to the geologic features of Maër Island and our statements have received the benefit of his able criticism; moreover, the geological conclusions presented herewith are in essential accord with those of Haddon, Sollas, and Cole in Transactions of Royal Irish Academy, vol. 30, 1892–1896, pp. 419–476, pls. 22–25; also, as a matter of historical interest, one should read J. B. Jukes, on the Voyage of the *Fly*, vol. 1, chapters 8 and 13, London, 1847.

The growth and development of the fringing coral reefs has been profoundly influenced by the outflow of silt and sand from these brooks and from the lava and ash slopes of the island, while in other places, as at the western corner of the island, the reef-flat has been encroached upon by sand dunes composed of wave-washed volcanic and calcareous fragments. Hence, if we are to understand the conditions which have affected the history of the reefs, we must take into account those of the land itself and of the ocean currents which impinge upon the eastern shore and then sheer around the northern and southern ends of the island. Wherever the water is agitated, cool and free from an excess of silt, the reef-flat is wide and covered with living corals, but wherever it is calm, hot, and depositing silt the reef-flat is narrow and the corals deficient. Indeed, it was at Maër Island that the author found that, generally speaking, the effects of silt and of temperature are coördinated; those corals which can withstand high temperature being also those which are most resistant to the smothering effects of silt. Thus, certain forms thrive best in the heated shore-waters not only because they can withstand the high temperature, but because they are not easily asphyxiated by silt; and, conversely, corals which live in the cool waters of the seaward regions of the reef-flats are the species which are easily smothered by silt or killed by high temperature.

Maër Island is completely surrounded by a recent coral reef which is especially interesting because no hurricanes have been known in this region, and thus the corals grow on uninterruptedly and without the periodic destruction of vast masses, such as occurs along the Great Barrier Reef south of Cairns. In fact, along the entire windward shore of Maër Island one was able to find only two small pieces of branching *Porites* which had apparently been cast upon the beach. In contrast with the many large stranded coral heads seen upon the shores of Pacific islands in regions subject to hurricanes,

this appears remarkable and shows that at least one of the chief agents which interfere with the growth of corals is absent from the Murray Islands. If in a hurricane region, the wide floor of the southeast reef-flat would be smooth, hard rock with but little coral upon it, as are the shore-flats of the Paumotos Islands; but at Maër Island the reef-flat is densely covered with one of the most luxuriant coral growths to be found in the Pacific.

Moreover, there are no "negro-heads"[1] over these Murray Island reefs, nor indeed over any of the numerous reefs of Torres Straits which the expedition visited, from Cape York to New Guinea. It will be recalled that, as a result of his exploration, Alexander Agassiz,[2] 1898, supposed these limestone masses projecting above high-tide level to be vestigial remnants of elevated reefs, and Semper[3] held the same view respecting large stranded coral blocks upon the Pelew Island reefs, but Hedley and Griffith Taylor, 1907,[4] and also F. Wood Jones in his "Coral and Atolls," have advanced reasons supporting the contention that they are merely fragments which have been dislodged and then washed inward from the outer edges of the reef in time of hurricanes and finally, in some cases, recemented to the reef-flat by the formation of beach-rock, bryozoa, lithothamnion, nullipores, or growing coral around their bases. In support of Hedley and Griffith Taylor's view we have the fact that the coral reefs of Torres Straits and southeastern New Guinea, which are free from hurricanes, exhibit no "negro-heads," and yet these are found in abundance over those reefs of the Great Barrier from Cooktown southward which are subject to hurricanes. Erratic boulders of living or dead coral are indeed found scattered over the reefs of Torres Straits; but these are all so small that they do not project above the surface excepting at the lowest tides. In short, one finds no geologic evidence of there having been hurricanes at the Murray Islands and there are no native traditions mentioning such phenomena.

It thus appears that conspicuous "negro-heads" are found only upon those reefs of the Great Barrier region which are subject to hurricanes.

The rapidity with which an erratic boulder may become cemented into a reef-flat by coquina or beach-rock is remarkable;[5] for at the Murray Islands many of the recent mollusks which are imbedded in coquina just above high tide have their nacre wel preserved, and a piece of granite similar to that of Cape York and which had evidently been transported to Maër Island through human agency, probably as ammunition for slings, was found firmly imbedded in hard coquina at high-tide level.

[1]Flinders gave the name "negro-heads" to coral boulders which project often above high-tide level and are scattered over the reef-flats of the Great Barrier Reef, especially in the neighborhood of Cairns.

[2]Bulletin of the Museum of Comparative Zoology, vol. 28, pp. 114 and 121.

[3]Semper, K., 1881, Animal Life, p. 239; International Scientific Series, Appleton.

[4]Hedley and Taylor, Coral Reefs of the Great Barrier, Queensland; Australian Association for Advancement of Science, Adelaide Meeting, 17 pp., 3 pls., 1907.

[5]Cyril Crossland, 1911, Journal Linnean Society of London, vol. 31, p. 279, describes this process at Khor Dongonab, Red Sea. Here beach-sand draws up sea-water through capillary action; then this sea-water evaporates and finally the rains remove the more soluble, leaving the less soluble constituents of the sea salts as a cement which converts the originally loose sand into stone.

The richness of the Murray Island reefs is due, however, not wholly to their freedom from the destructive effects of severe storms, but to the purity of the deep blue ocean water which lies close to the eastward of them; for here, near the outer edge of the Great Barrier Reef, we find little of the suspended silt which seriously interferes with coral growth around the off-lying islands of Cape York, Australia; nor is there any trace of the muddy shore-water of New Guinea which keeps open the wide Bligh Entrance lying off the great swamps of the Fly River region.

In common with other islands of Torres Straits, the recent reef-flats surrounding the Murray Islands are much wider on the southeast than on the northwest side of the islands, the reefs having grown mostly to the windward. The strong southeast trade-wind, which prevails for about eight months of the year, causes the ocean water on the incoming tide to sheer near the middle of the southeast side of Maër Island, the currents parting, the stronger going around the southwestern and the weaker around the northeastern end of the island. The current around the southwestern side is reinforced by that around Dowar Island and is thus stronger than that around the northeastern end. The silt from Haddon and Hedley brooks is thus carried around the southwestern end of the island and contributes to form the sand dunes which are about 20 feet high and to partially cover and smother the reef-flats at the western corner of Maër Island. (See map, plate 2; and plate 5 B.) Several smaller sand dunes on the northern corner of the island are also formed by the weaker northwesterly currents and thus the northwest side of the island is concave and lined throughout by a sand-beach formed of volcanic and calcareous fragments. It is interesting to observe that the sand derived from these currents is tending to change the original oval shape of the island into a crescent, reminding one of the manner in which an atoll islet acquires its typical crescentic shape, as shown by Guppy,[1] Hedley and Taylor, Wood Jones, and Vaughan. The outflowing currents due to the falling tide are not competent to offset this effect, for they must make their way against the prevailing southeast wind. At the Murray Islands the tide rises between 7 and 8 feet, thus producing spring tide currents of nearly 4 knots an hour around the southern end and a flow of about half that rate around the northern end of the island.

Measured from the shore-line at mean high tide, the reef-flat from the middle of the southeast side of the island to the northern corner is from 1,800 to 2,200 feet in width. At the middle of the northwest side it is 780 feet wide, while off the sand dunes at the western corner the outer edge of the reef is only 175 feet from shore, about 85 feet of this distance being submerged sand-beach, which is laid bare at low tide, thus leaving only about 90 feet of *Sarcophyton* and other alcyonaria and coral-bearing reef-flat. Around the southwestern end of the island the reef-flat is about 400 to 600 feet in width.

[1]Guppy, Scottish Geographical Magazine, vol. 5, pp. 472–474, 1889.

From the middle of the southeast and along the east and northeast sides of Maër Island the reef forms a wide submerged platform covered by a depth of less than 2 feet at low tide, while along its seaward edge there is a "lithothamnion ridge," about 150 feet wide and elevated 6 to 8 inches above the low-tide level of spring tide. We will speak later of the structure of this so-called "lithothamnion ridge"; at present it suffices to say that it serves as a dam to impound the water of the great shallow southeast reef-flat at low tide, thus forming a veritable tidal lake about 1,600 feet wide, 8 to 17 inches deep, and more than 2 miles long, from which the water can not escape even though the tide sinks to a lower level on the ocean beyond the reef. A rich growth of corals is found within this marine basin, protected as it is from breakers by the lithothamnion ridge and from the disturbing influences of strong currents by its wide expanse of shallow water.

No heavy breakers appear to reach the southeast shore at any time, for even during storms the sea expends its force upon the crest of the lithothamnion ridge. Thus only small shells and pebbles are at present cast ashore along the southeastern side of the island; yet this whole shore-line is bestrewn with large, rounded, beach-worn boulders of black lava which were driven shoreward, rolled in the surf and stranded before the time when the fringing reef grew seaward and caused the breakers to expend their force far out from the original shore-line. (See plate 5 A.) In common with other islands of the Torres Straits region, whether volcanic, calcareous, or continental in character, the Murray Islands exhibit a recently emerged shore platform about 3 feet above the present high-tide level,[1] and wave-worn lava boulders are now found strewn above high-tide level along the entire southeast side of the island and between Hedley Brook and Haddon Brook. (See plate 4 B.)

The remarkable richness of the southeast reef is probably due in great measure to the pure ocean water which the southeast trade-wind drives constantly upon it, thus bringing an abundance of pelagic life to provide food for the corals, cooling and aërating the element in which they live, and enabling the corals to free themselves from silt through the beneficent effect of agitation.

In contrast with the rich southeast reef-flat, those of the southern and northern ends of the island are relatively devoid of corals, the flats here being covered with drifting silt and sand, which is fatal to madreporean coral growth, although not unfavorable to alcyonaria, such as *Sarcophyton*. The precipitous outer edges of these reefs are, however, remarkably rich and the largest individual coral heads to be found around the entire island are those at or near the outer edge of the reef-flat of the southern and southwestern sides of the island.

At the northern end of the island the drifting silt forms a small oval sand-bar, about 1,640 feet from shore, 150 feet wide, and elevated about 2 feet above low-tide level. (See plate 2.) This sand-bar is composed of fine

[1]At Vivien Point, Thursday Island, large heads of *Symphyllia* and *Mæandra* were found by the author *in situ* in the limestone in which they grew, but they are now emerged about 3 feet above the highest tides.

volcanic and calcareous particles which have evidently been swept along and over the northeastern reef-flat by the current due to the southeast trade wind and the strong incoming tide.

The mud from Haddon Brook and Hedley Brook prevents a vigorous coral growth along this part of the shore, and the reef-flat is here dead and covered with silt, only its wave-washed outer edge and its precipitous seaward slope affording foothold for successful coral growths. Similarly the silt from these brooks is carried around the southwest side of the island, sweeping over the reef-flat and killing most of the corals excepting those near the outer edge of the reef, where the largest coral heads of the island are found. Indeed, where silt is being drifted over a bottom only large coral heads which project above it can thrive.

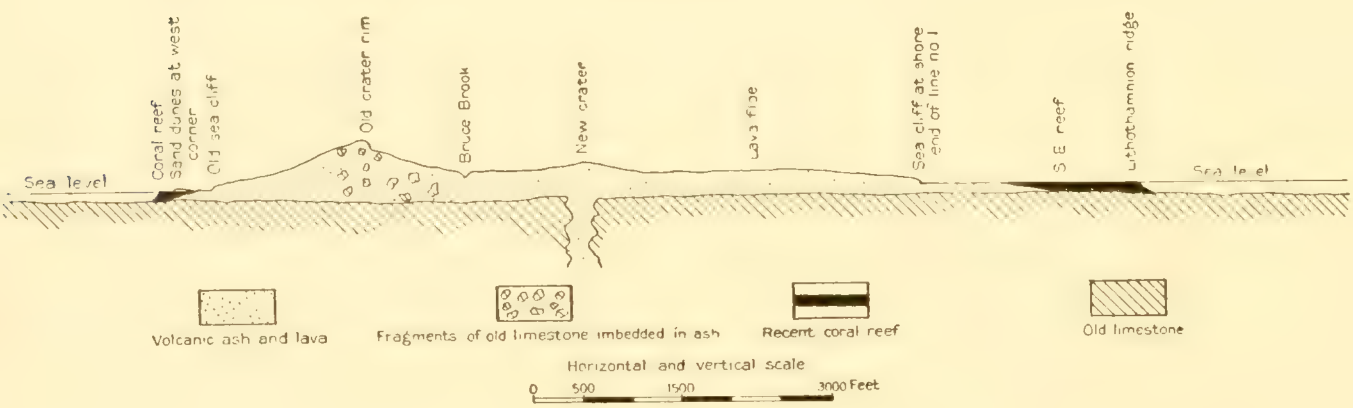

FIG. 3.—Section of Maër Island through the shore end of Line I, and the western corner of the Island.

The seaward wall of the reef surrounding Maër Island is from 15 to 30 fathoms in depth, this being the depth of the submarine plateau above which the modern fringing reefs have arisen.

R. T. Hill in 1899[1] pointed out "that Jamaica was once a more extensive land than now, with benched and terraced margins which were submerged by subsidence," and that "similar submerged plains are now occupied by the growing reefs around the island." A. Agassiz in 1894[2] said:

"In fact, what I have seen so far in my exploration of the coral reefs of the West Indies would show that wherever coral reefs occur, and of whatever shape, they form only a comparatively thin growth upon the underlying base, and are not of great thickness. In Florida they rest upon the limestones which form the basis of the great peninsula. On the Yucatan Bank they are underlain by a marine limestone. In Cuba they abut upon the Tertiary limestones of its shore. Along Honduras, the Mosquito Coast, and the north shore of South America, they grow upon extensive banks or shoals, parts of the shore plateau of the adjoining continent, where they find the proper depth."

Agassiz and others had adduced evidence indicating recent submergence in the Bermudas and the Bahamas. Information regarding other coral

[1]Mus. Comp. Zool., Bull., vol. 36, pp. 99, 100, 1899. [2]Mus. Comp. Zool., Bull., vol 26, p. 172, 1894.

areas in the western Atlantic, the Gulf of Mexico, and the Caribbean Sea was gradually accumulating. Heilprin in 1891[1] said regarding Yucatan, "the evidence is all but conclusive that there has been recent subsidence." Hayes in 1899[2] showed conclusively that in Nicaragua there has been recent submergence following a higher stand of the land and a period of gorge cutting. In 1902, Hayes, Vaughan, and Spencer[3] showed that in Cuba there has been recent submergence, corroborating an opinion of Crosby published in 1883.[4] Branner[5] in 1904 adduced evidence indicating submergence of the lower reaches of drainage courses and the formation thereby of the harbors of the east coast of Brazil. He places the submergence in "probably" early Pliocene time, since when there has been emergence of about 8 meters, in places.

E. C. Andrews[6] in 1902 published as his conclusion, after a study of the Queensland coast and the Great Barrier Reef of Australia, that the reef is growing upon the submerged part of the Australian continental shelf, and that "the continuance in width of the shelf southward of the reef limits (coralline), and the great shoals thereon, points to a minor part only of the shelf being formed of coral growth."

Evidence of recent submergence of former shores of Pacific islands definitely dates from the days of Dana, and during recent years has been increased in volume through efforts of many investigators.

Reginald A. Daly[7] in 1910 and again in more recent publications[8] has called attention to the similarity in general depth of off-shore reef-bearing platforms, such as that of the Great Barrier and the average depth of the lagoons of coral atolls. Moreover, the generally flat and uniform character of the bottoms of atoll lagoons and of the submerged platforms upon which barrier reefs have arisen may indicate that the ocean's surface was at a lower level in the ice age, the water having been taken out of the ocean to form the ice caps surrounding the poles, upon which the attraction of this vast mass of ice would still further lower the surface of the tropical seas by about 8 feet, in the manner described by R. S. Woodward.[9] Moreover, the cold of glacial times might be fatal to many coral reefs and thus, according to the hypothesis of Daly, the present reefs have grown since Pleistocene times on drowned platforms of marine erosion. Certainly the modern reefs of the Murray Islands are placed upon a submerged limestone platform, but its manner of origin and its age will not here be discussed.

Vaughan has, during the past sixteen years or more, been active in the investigation of the geologic conditions favorable for coral reef develop-

[1] Proc. Acad. Natural Sci., Phila., p. 148, 1891.
[2] Geol. Soc. Amer., Bull., vol. 10, pp. 339–340, 1899.
[3] Geological Reconnaissance of Cuba, pp. 16–18, 32, 33, 115, 116, 1902.
[4] Bost. Soc. Nat. Hist., vol. 22, p. 128, June 1883.
[5] Mus. Comp. Zool., vol. 44, pp. 169, 170, 1904.
[6] Proc. Linn. Soc., New South Wales, pt. 2, pp. 146–185, 1902; also Amer. Jour. Sci., vol. 41, pp. 135–141, 1916.
[7] Daly, R. A., 1910, Amer. Jour. Sci., vol. 30, pp. 297–308.
[8] *Idem*, 1915, Proc. Amer. Acad. Arts and Sci., vol. 51, pp. 159–251; 1916, Amer. Jour. Sci., vol. 41, pp. 153–186.
[9] Woodward, R. S. 1888, Bull. U. S. Geol. Surv. No. 48, pp. 40, 70.

ment and in ascertaining by extensive field study the exact relations the reefs, both fossil and Recent, in Florida, the Bahamas, the West Indies, and Central America, bear to the geologic history of the areas in which they occur. In his article, which follows this paper, he gives a list of his publications; references to some are in the footnote[1] below. He has greatly multiplied the evidence in favor of recent submergence in the coral-reef areas in the western Atlantic, the Gulf of Mexico, and the Caribbean Sea, and has shown that the living offshore reefs have formed either during or after submergence and are growing on submerged basement platforms where conditions are favorable for the life of reef-forming corals. The platforms continue beyond the northern or southern limits of the reefs and their existence is in no wise dependent upon the presence of reefs. Vaughan's explanation is, therefore, similar to that announced by A. Agassiz, except that he takes into account geologically Recent submergence. The explanation of Andrews for the Great Barrier Reef of Australia and that of Vaughan for the Floridian, West Indian, and Central American reefs are identical.

Vaughan has also shown that the Great Florida Plateau has existed as a plateau since at least late Eocene time; and that some of the West Indian platforms are about as old. As these platforms existed previous to Pleistocene time they could not have been formed by marine planation during Pleistocene glaciation. Whatever be the cause of shift in position of strandline, off-shore reefs form on submarine flats during or after rise in sea-level, provided the rate of submergence be not too rapid, and the amount be not too great. This explanation applies to the fossil reefs of Florida and the West Indies as well as to the reefs living today. He has recently pointed out in the Virgin and northern Leeward Islands and off the shores of Central America certain submarine terrace flats, one at a depth of about 17 to 20 fathoms, another at a depth of about 26 to 30 fathoms, the deeper flat being separated from the shallower by an escarpment. These relations accord with the demands of the Glacial control theory as expounded by Daly.

It is obvious that the views of Andrews, Daly, and Vaughan[1] have much in common, but are in marked contrast with those of Murray[2] and of Agassiz, who maintain that lagoons of barrier reefs and atolls are largely due to solution, or of W. M. Davis[3] and P. Marshall[4], who support the Darwinian subsidence theory of reef formation, while Daly, Wood Jones, Hedley and Taylor, and Vaughan deny the efficacy of solution, and Gardiner and Guppy consider solution to be an important factor. Clearly the subject of the formation of barrier reefs and atolls is far from being settled in the minds of its students.

[1]Vaughan, T. W., 1914, Bull. Geol. Soc. Amer., vol. 26, p. 58; *also* 1914, Bull. Amer. Geog. Soc., vol. 46, p. 426; *and* 1915, Abstracts of Papers, Geol. Soc. Amer., 28th Annual Meeting, p. 19.

[2]Murray, J., 1880, Structure and Origin of Coral Reefs and Islands, Proc. Roy. Soc. Edinburgh, vol. 10, p. 505.

[3]Davis, W. M., 1915, Amer. Jour. Sci., vol. 40, pp. 223–271, 9 figs.; also Scientific Monthly, 1916, vol. 2, pp. 313–333; 479–501; 557–572; also Proc. National Acad. Sci., vol. 1, pp. 146–152; vol. 2, pp 284–288; 466–475.

[4]Marshall, P., 1912, Australasian Association for Advancement of Science, vol. 13, pp. 140–145, pls. 10, 11.

As Daly states, the Darwin-Dana subsidence theory fails to explain the fact that throughout the Pacific and Indian Oceans the bottoms of the lagoons of barrier reefs and atolls are extraordinarily flat plains sunken to a nearly uniform depth of 20 fathoms; and, as pointed out by Andrews and Vaughan, it does not explain the extension of the platforms into cold regions where corals cease to grow. The coral reefs rise abruptly as patches above or as mere walls along the seaward edges of these platforms. In fact, as recently pointed out by Vaughan, the Great Barrier Reef of Australia does not throughout its length always margin the Australian continental shelf, for near its southern end the reef stands back some distance from the seaward edge of the shelf. If various more or less local submergencies caused atoll lagoons they ought to range considerably in depth, but as Daly shows, the maximum depth in any coral lagoon is only 49 fathoms (91 meters) in Budd-Iambu, Fiji. The Daly theory readily explains the flat bottoms and uniform depths of lagoons, but the submarine platforms appear in places to be too wide to have been formed during the glacial epoch, and indeed, while Daly points this out, Vaughan has shown that some platforms date from old Tertiary times (Eocene and Oligocene).

The Murray-Agassiz solution theory is weak in that tropical (Tortugas) sea-water dissolves limestone at so slow a rate that the lagoons could not have been appreciably deepened in this manner. There are, however, other agencies which dissolve limestone, and these may be more or less effective, such as holothurians and fish which swallow large quantities of sand, but most if not all atoll lagoons are filling up more rapidly than they are dissolving out. Moreover, it is difficult to explain why, if solution is so effective in shallow water, it should suddenly decline at depths below 20 fathoms. Agassiz's idea of scouring due to attrition over the bottoms of lagoons is a factor worthy of consideration, but it has not been quantitatively evaluated.

The average upward rate of coral growth, being from 6 to 20 mm. per year, is possibly more rapid than the average rate of sinking of oceanic islands which are subsiding; and if this be true the encircling reefs of most subsiding islands might be expected to maintain themselves at the surface in accordance with Darwin's hypothesis. Indeed, Davis (1915, American Journal of Science, vol. 40, p. 250) presents evidence tending to show that this occurred at Vanua Mbalavu, Fiji, and elsewhere, and it would explain the great thickness of many elevated coral reefs. Perhaps most volcanic islands tend temporarily to sink after they cease to be active, and, indeed, Daly's theory is not adverse to that of Darwin, but merely emphasizes the control which a temporarily lowered sea-level may have exercised over the *modern* reefs, and it seems not impossible that some of the pre-glacial reefs were built up upon subsiding foundations, whereas most of the modern reefs have grown upward upon drowned platforms which have for the most part remained stationary since Pleistocene times, the modern period having been too short to permit of many significant depressions or elevations of the reef regions.

Of the explanations so far proposed for living coral reefs, it seems that those supported by Daly, Andrews, and Vaughan[1] furnish the best working hypothesis. That there was withdrawal of water from the ocean to form the Pleistocene ice-caps, and that the water so withdrawn was returned to the sea with the melting of the glaciers seems undeniable. The amount of the lowering and subsequent restoration of sea-level can be only approximated, as the factors to be considered in making the estimates are not precisely known. However, it is interesting to note that recent computations are of the same order of magnitude. Thus W. J. Humphreys, at the request of Vaughan, made an estimate showing that the amount of lowering of sea-level was probably 67 meters,[2] while Daly in his recent paper (*op. sup. cit.*) estimates it as between 50 and 60 meters. The two estimates accord very closely. As the Glacial period is variously estimated as having been between 250,000 and 1,000,000 years in duration, there was time for considerable marine planation. The studies of Vaughan[1] on the physiography of the sea-bottom in the West Indies and Central America, and Daly's and Vaughan's profiles across the Australian continental platform and the Great Barrier Reef accord with the demands of Daly's Glacial Control theory, as evidence is adduced in favor of a Recent rise of sea-level by an amount approximating 25 fathoms. All Pleistocene and Recent changes in sea-level are surely not due solely to glaciation and subsequent deglaciation, but that the more important ones were in part or largely caused by such phenomena seems beyond doubt.

Daly and Vaughan agree as to the superposition of the living reefs on antecedent platforms, and both now agree that some platforms clearly antedate the Pleistocene, and thus their formation can not be referred to processes operative during that time; also both Daly and Vaughan agree that there is strong evidence in favor of the margins of such old platforms having been remodeled during Pleistocene time, while the sea stood at various positions lower than at present. The evident geologic antiquity of some platforms does not signify that others are equally old, and it is highly probable that many platforms were formed during the Pleistocene period.

As Vaughan, Daly, Davis, and others have shown shore-line history needs to be studied not only within coral-reef areas, but over other parts of the earth where sea-level intersects the land; the depth to which submarine planation is effective and its limiting conditions have not been adequately investigated; and but little trustworthy information is available on the rates at which the sea will cut away the land, and on the factors which determine the rates. The complex of causes which may result in shift in the position of strand-line, and the evaluation of the effects of each are among the problems before us; and the rates at which the sea-bottom may be aggraded is unknown.

[1] See especially his recent paper in Wash. Acad. Sci. Jour., 6, pp. 53–66, Feb. 4, 1916.

[2] Wash. Acad. Sci. Jour., vol. 5, pp. 445–446, June 19, 1915.

To Davis should be given the credit for having called renewed and prominent attention to the importance of making a careful study of shore-line topography in relation to the coral-reef problem.

To return to the consideration of Maër Island, the "lithothamnion ridge" extends only from the middle of the southeast side to near the northern corner of the island, this being the region subject to the sweep of the breakers due to the southeast trade wind.

On the northwest, south, and southwest sides there is no "lithothamnion ridge," for breakers rarely occur in these regions; moreover, the growth of the lithothamnion ridge is prevented along the southernmost half of the southeast side by the silt from Haddon and Hedley brooks; while Bruce Brook produces the same effect at the northern end of the island.

The structure of this so-called "lithothamnion ridge" is interesting. It consists of a nearly flat plateau elevated about 6 to 8 inches above low-tide level and usually about 150 feet wide at low spring tide. There are many shallow tide-pools over this ridge, but these are rarely more than a foot wide and 3 to 5 inches deep.

Numerous corals grow in these tide-pools, 201 living coral heads being counted within a 50-foot square at the crest of the lithothamnion ridge. These corals present a remarkable appearance; the branched *Acropora* and *Pocillopora bulbosa* are stouter-stemmed and more compact and rigid than are stocks of the same species which grow in the protected waters of the reef-flat a few hundred feet nearer shore. (See plate 12, figs. 1–3.) Moreover, the surviving stems of the branching corals nearly all bend inward toward the shore, reminding one of the gnarled and twisted trees one sees upon a wind-swept beach. There are many massive coral heads, such as *Goniastrea pectinata*, living within the cleft-like pools of the lithothamnion ridge, but most of them are hardly more than mere incrustations clinging to almost every crevice in the rocky floor of the shallow tide-pools over which the breakers dash in full force. As is well known, the effects of environment upon the growth-forms of corals have been especially discussed by von Marenzeller, 1906, in his work on Red Sea corals, by Pace, who observed *Turbinaria* in Torres Straits, and also by Wood Jones and by J. Stanley Gardiner, in their studies of Cocos Keeling and of the Maldive Archipelago, respectively; and by Vaughan in several publications. Especially interesting is the account which Wood Jones gives in his "Coral and Atolls," 1912, pp. 69–134.

All corals in the tide-pools of the lithothamnion ridge are cut off squarely at the low-tide level of the water contained in the tide-pool and thus they are usually not more than 2 to 5 inches high, although in the larger pools they may be a foot or more in width.

All dead parts of these corals are incrusted with a growth of Lithothamnion, Bryozoa, and nullipore algæ, which also form a general veneer over the rocky crest of the ridge. Thus, upon a superficial inspection the ridge

appears to be composed of these veneering organisms, but in reality it consists of *dead corals* which have been protected from erosion by a thin coating of organic material. The dead-coral element is the dominant one, although hidden from sight, while the veneer which is so apparent is merely superficial, covering the dead surfaces of the corals and filling the interspaces between them in the manner of a cement.

There is no lithothamnion ridge along the outer edge of the reef which fringes the northwest side of the island, for breakers appear on this shore only during the occasional storms of the season of northwesterly winds from November to March and the incrusting nullipores thrive only where the breakers dash continually over the reefs.

The northwest reef-flat slopes gradually seaward, the water being about 3 feet deep along its precipitous outer edge at spring tide. Near shore one finds extensive grass-flats composed of *Posidonia australis*, among which are large areas of *Montipora ramosa*, which are laid bare by even moderately low tides. The outer edges of this reef-flat are covered with well-developed stocks of *Acropora hebes*, *A. pulchra* var. *alveolata*, etc., the stems of which may project 6 inches or more above the level of low spring tide. Here, as elsewhere around the island, the seaward edge of the reef-flat ends in a steep slope extending abruptly downwards to a depth of 15 to 30 fathoms. Fragile corals, such as *Acropora* and *Montipora*, which require pure, cool, relatively quiet water, grow upon the wall of this precipice; but the southeast trade wind blew so constantly during September and October that no detailed study of this outer slope could be made.

On the southeast side of the island, where the reef-flat is widest, waveworn lava boulders are strewn along the shore and extend outward fully 200 feet from mean low-tide line. These boulders have been used by the natives to construct the walls of the numerous fish-traps which extend outward about 350 to 390 feet from mean high-tide line. (See plate 5 A and plate 6 B.)

The steep lava bluff fronting the whole northeasterly and the more easterly part of the southeast side of the island is about 20 to 30 feet high, and this (together with the wave-worn masses of lava boulders at its feet) leads one to believe that it has been eroded and encroached upon by the sea. Judging, indeed, from the trend of the fairly regular slope above the shore-bluff (see figs. 2 and 3) the shore was originally about 400 to 600 feet farther out than at present. If this be true the reef-flat has extended seaward about 1,200 feet beyond the old shore-line, but in default of a series of borings through the reef this is at best only a matter of conjecture.

The entire visible reef belongs to the recent period subsequent to the cessation of volcanic activity and has evidently grown seaward over its own talus, so as to widen the reef-platform surrounding the island, and (as is commonly the case in the Pacific) the sea front of the reef-precipice is densely covered with corals, those in relatively quiet water at depths of a fathom or more being mainly foliated, fragile, rapidly growing forms, such as *Montipora*.

Thus the reef extends seaward at a rate dependent upon the average growth-rate of densely clustered coral heads and if this be taken at one-half inch per annum the wide southeast reef-flat of Maër Island might have been formed in 28,800 years, although one must not take such an estimate at all seriously, for many factors may enter into the case which we have not evaluated.

Considering Maër Island as a whole, it appears that where the reef is fully exposed to the breakers of the southeast trade-wind and is fairly free from silt it grows rapidly seaward. In silted regions and in quiet water, however, the reef does not grow so rapidly. For their best development corals require pure, moderately agitated water; only a few forms, such as *Porites andrewsi* Vaughan and *Cœloseris mayeri* Vaughan, thrive best in semi-stagnant regions where the bottom is muddy. The most luxuriant growth of corals on the southeast reef is found about 200 feet inward from the innermost wash of the breakers, at 1,400 feet from shore. Seaward from this region the corals thrive well, but are apt in time of storm to become broken by the surges.

ANNUAL GROWTH OF CORALS.

As the coral reefs of the Murray and other islands of Torres Straits have apparently grown seaward over their own outer slopes during the recent period of quiescence, it becomes important to know something respecting the rate of growth of reef corals in this region. Fortunately, for this purpose certain corals lying off Vivien Point, Thursday Island, were measured and photographed by Saville-Kent in June 1890. On November 4 to 10, 1913, some of these corals were identified by the present writer with certainty; while others had evidently disappeared or died, or could not be recognized from Saville-Kent's description. Thus, the large *Goniastrea* in the foreground of Saville-Kent's Plate II of his "Great Barrier Reef of Australia" has disappeared, and we were told that a number of coral heads were gathered from this region about ten years ago and used for making a retaining wall for the road along the shore. The *Symphyllia*, which occupies a prominent position on the extreme right in the plate just referred to, on November 8, 1913, was 74 inches in its longest diameter, N. 15° W. to S. 15° E., and 65 inches in the diameter transverse (90°) from the longest. The upper surface of this coral is now largely killed, the dead area being 53.25 inches by 43.75 inches with an isolated

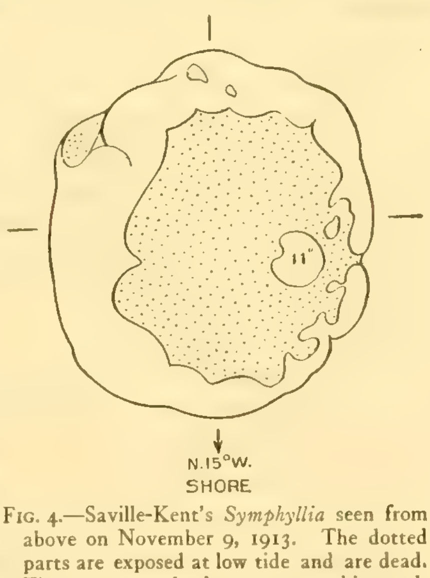

Fig. 4.—Saville-Kent's *Symphyllia* seen from above on November 9, 1913. The dotted parts are exposed at low tide and are dead. There were no dead areas upon this coral-head in 1890 and it was then regular and dome-shaped; now it is flat and mainly dead above, but growing laterally.

rounded patch of living polypites 11 inches in diameter near the western side of the dead area. When Saville-Kent measured this coral in June 1890 he found it to be 30 inches in diameter and dome-shaped; thus it has apparently increased 44 inches in diameter in 23.33 years or at the rate of 1.88 inches (48.75 mm.) per annum.

The large "light brown *Porites*," ("*P. astræoides*") shown in figure 1 on page 8 of Saville-Kent's "Great Barrier Reef," and which he states was 19 feet wide in 1890, is now 22 feet 9.5 inches wide. Thus it appears to have increased in width by 45.5 inches during the past 23.33 years, or at the rate of 1.95 inches per annum.

On the other hand, the "gray-green *Goniastrea*," which Saville-Kent states to have been 8 feet 2 inches wide in 1890, was 8 feet wide according to my measurements on November 9, 1913, and therefore it appears to have grown but little if at all during the past twenty-three years, and in conformity with this conclusion we may observe that the "2-foot channel" described by Saville-Kent, which extended in 1890 between this "gray-green *Goniastrea*" and the "light brown *Porites*," has been reduced to a mere cleft not more than an inch or two in width; it thus appears to have been closed solely by the growth of the *Porites* and not by that of the *Goniastrea*.

Saville-Kent speaks of a submerged *Porites* covered by *Pocillopora* 10 inches in diameter (fig. 2, page 8). The *Pocillopora* has disappeared, but a submerged *Porites* apparently occupying the same situation near the *Symphyllia* was 16.5 inches wide in its widest diameter, in November 1913.

We are led to conclude that, while some of the large massive reef corals increase in diameter at a rate of nearly 2 inches per annum, others (such as the "gray-green *Goniastrea*") may, after attaining a certain size, cease growing. Indeed, Vaughan has already observed that this was the case with most if not all of the Florida corals and he also showed that large stocks which had practically ceased to grow or were growing very slowly could be induced to resume a rapid growth-rate by breaking them apart and planting the fragments in concrete.

The more fragile coral stocks, such as *Acropora* and *Pocillopora*, are either short-lived or easily destroyed, for none of those seen and measured by Saville-Kent in 1890 could be found in 1913.

It is evident that if large massive coral heads (as *Porites* and *Symphyllia*) can add nearly an inch to their radius each year, they could fill up a channel at the rate of almost a foot in twelve years, which is fairly close to Gardiner's estimate, based upon a study of the growth-rate of Maldive Island corals, that they might build a reef at the rate of a foot in eleven and a half years, or as Gardiner puts it, 14.5 fathoms in one thousand years.[1]

Although the growth-rate of corals has attracted attention from the earliest times, yet records of carefully made measurements are rare in the

[1]Gardiner, J. Stanley, 1903, Fauna and Geography of the Maldive and Laccadive Archipelagoes, vol 1, pp. 327–333.

literature of the subject. By far the most complete are those of Vaughan upon the reef corals of Tortugas, Florida, and of Andros Island in the Bahamas. Also, recent observations of value have been made by Guppy, J. Stanley Gardiner, and Wood Jones upon corals of the Indian Ocean, and a paper embodying these results has been published by Wood Jones.

Vaughan has presented a paper upon this subject together with tables in the year book of the Carnegie Institution of Washington for 1915, No. 14, pp. 221–231.[1] According to Vaughan, *Orbicella annularis*, which forms large compact dome-like heads upon the Florida and Bahama reefs, grows upward from 5 to 6.8 mm. per year, while the branching *Acropora palmata* grows upward at rates between 25 and 40 mm. per year.

Observations upon Pacific corals are by no means so trustworthy as those of Vaughan upon the Atlantic forms, for the growth period is not so accurately known and the measurements were not so carefully made. However, Guppy[2] concludes that in the Cocos-Keeling Islands massive forms of *Porites* grow upward between 12.7 and 19 mm. per year, while the branching *Porites* (*palmata?*) grows about 30 mm., and certain forms of *Montipora* and *Acropora* at least 100 to 125 mm. per year. Also, Sluiter,[3] states that a young reef at the Black Cliff, Krakatoa, grew to a thickness of 200 mm. in not more than five years, and Gardiner (in his report upon the coral reefs of the Maldives and Laccadives) states that the upward growth of *Perforata* is about 20 mm. per year, while that of the massive Astræidæ is 22 mm. and of Fungidæ 29 mm. per year. The general average for about 28 species of corals is 25.6 mm. per year.

The observations and estimates of growth-rate of Pacific corals are consistent in indicating a more rapid rate than has been determined by Vaughan for Atlantic corals. This may be due to errors in the less careful measurements made in the Pacific; but their consistency *inter se* inclines one to suspect that in coördination with the greater richness, both in species and individuals, the growth-rate of Pacific reef-corals may be more rapid than that of corresponding genera in the Atlantic. In common with other cœlenterates the growth-rate of corals probably depends upon the abundance of food and thus a comparative study of the conditions of the supply of zoöplankton in the tropical Atlantic and the Pacific to the corals might throw light upon the question.

Thus in the Florida-Bahama region the corals usually grow near the outer edges of extensive, shallow limestone flats, the water over which is charged with precipitated calcium carbonate, which is fatal to most pelagic animals. In the Pacific, however, the reef flats are usually deeper, the precipitated limestone is less, and the pure ocean water, with its freight of pelagic life, is more accessible to the corals than in the Atlantic.

[1]Also in Journal Washington Acad. Sci., vol. 5, pp. 591–600.
[2]Guppy, 1889, Scottish Geographical Magazine, vol. 5, pp. 573–575.
[3]Sluiter, 1889, Natuurkundig, Tijdschrift Nederland. Indië, vol. 49, p. 375.

ASSOCIATION AND DISTRIBUTION OF CORALS.

In order to carry out a statistical study of the associations and abundance of the various species of corals growing upon the great reef-flat of the southeast side of Maër Island, a line (Line No. I, see map of Maër Island, plate 2) was surveyed across the reef. The shore end of this line was 1,496 feet in a northeasterly direction from the mouth of Haddon Brook, this position being just beyond the third stone fish-trap to the northeastward of Haddon Brook. (See map of Maër Island, plate 2 and plate 6 B.) Line No. I was run in a direction S. 39° E. and marked at intervals of 200 feet by stakes driven into the rocky floor of the reef-flat. The depth of water at low spring tides and the character of the bottom are shown in tables 1 and 2. Table 1 gives a brief summary, while table 2 presents the results of observations more in detail; and these tables may serve to give a general idea of the changing character of the coral-growth and of the bottom as one proceeds outward from the shore.

TABLE 1.—*Depth of water at extreme low spring tides during September and October 1913, over Line No. I across the southeast reef of Maër Island, Murray Islands, Great Barrier Reef of Queensland.* [This line is 1,689 feet long and extends S. 39° E. across the reef.]

Distance from shore measured from mean high-tide line.	Depth of water.	Remarks.
feet.	*inches.*	
200	4	Bottom of firm limestone mud about 4 inches deep, overlying volcanic rock and thickly covered with sea-grass *Posidonia australis*. No corals here.
400	4.5	Bottom same as before. A few living corals on erratic limestone boulders which have been driven shoreward by storms. Many sponges, Holothuria, and blue star-fishes (*Linckia lævigata*).
600	6.5	Clean sandy bottom, overlying limestone rock, without *Posidonia*. *Porites* and small stocks of *Pocillopora bulbosa* are conspicuous.
800	10.5	*Seriatopora hystrix* is here the most conspicuous coral. Bottom rocky, covered thinly in places with limestone sand.
1,000	16.25	*Seriatopora* is here at its acme and covers about a third of this area. It forms masses 4 to 7 feet in diameter, the upper surface being flat and killed at the level of low tide. Bottom of limestone rock.
1,200	8.5	*Seriatopora* is still the dominant coral, but the stocks are all small, evidently being broken in time of storms.
1,400	14.5	Species of *Acropora*, especially *Acropora pulchra, hebes*, etc., are here the most conspicuous corals. Bottom rocky and broken. Coral growth is here most vigorous. This is about 200 feet inward beyond the usual surge of the breakers.
1,600	9.5	The rigid stems of *Acropora palifera* constitute the most conspicuous coral, but the nodular forms of *Porites* are much more numerous; but due to the strong wash of the breakers, only the stouter and more massive forms of corals can thrive well in this region, and fragile, slender-stemmed forms (such as *Seriatopora*) are found only in protected crevices. Although most of the coral heads suffer here by rough treatment from the surges, yet this is the region where one finds the greatest number of *species* of corals, and this despite the fact that coral stocks are not so numerous here as they are 200 feet nearer shore, where the water is less agitated. Thus more *kinds* of corals live in the region of the breakers than at any other part of the reef-flat.
1,780	About 8 inches *above* low-tide level.	This is about the middle of the so-called lithothamnion ridge, a smooth, flat, wave-worn rocky plateau with many small, shallow, crevice-like tide pools, very few of which are more than 6 inches deep.
1,869	About 14 inches deep.	This is on the edge of the submarine precipice which forms the seaward front of the reef and which falls off rapidly into about 25 fathoms.

TABLE 2.—*Depths of water and character of bottom along Line No. I of the southeast reef of Maër Island, Murray Islands, Queensland, Australia. The depths are those of the water at extreme low spring tides during September and October 1913.*

Distance from shore measured from mean high-tide line.	Depth of water at low tide.	Character of bottom.
feet.	*inches.*	
200	4	Thin layer of limestone mud overlying a firm hard bottom of lava rock, covered quite thickly with *Posidonia*. There are no corals here. The tide goes out almost to this point and even 70 feet beyond it in places. The bottom consists largely of finely broken shells of mollusca and minute fragments of coral. There are no coral heads of any sort here, not even dead and corroded coral blocks.
400	4 5	Bottom of firm limestone mud, consisting of broken and dead fragments of shells, corals, etc., and thickly covered with *Posidonia*. Loose corroded blocks of dead coral evidently driven inward from the outer parts of the reef-flat are found here, and the only living corals growing here are attached to these blocks. These blocks of dead coral do not commonly occur within 350 feet of the shore and evidently the waves (even in time of storm) have not sufficient force to drive them ashore. *Holothuria atra*, sponges, and blue-star fishes (*Linckia lævigata*) are common here. The *Posidonia* extends about 460 feet out from the shore, beyond which the sandy bottom is barren of green seaweeds save for a few Nullipore algæ.
600	6.5	Bottom barren of green sea-weeds, firm and sandy, and composed of finely broken shells and fragments of other limestone-bearing organisms. Most of the corals are growing upon eroded flat blocks of limestone which the waves in time of storm have evidently driven inward from the outer parts of the reef. *Pocillopora bulbosa* is a dominant coral, but the species of *Porites* are even more abundant. At about 500 feet from shore *Porites andrewsi* is one of the commonest corals, but it declines in numbers as one goes outward over the reef, and practically disappears about 1,100 feet out from shore.
675	8	The corals here are chiefly attached to the bare limestone floor of the reef, although there is still much coral sand and many flat, unattached corroded coral blocks. Branching *Acropora* appear here, and small stocks of *Seriatopora hystrix* are rather common.
800	10 5	*Seriatopora* is now the dominant coral, forming clusters which often become conjoined and may be 5 to 7 feet in diameter. They are all killed at low-tide level, and are thus flat-topped and dead above, only the outer margin being alive and growing. Several nodular forms of *Porites*, branching *Acropora*, *Goniopora*, and *Pocillopora* are represented in the order named, the commonest being first named. The bottom here is hard limestone with but little coral sand.
1,000	16 25	The *Seriatopora* is here at its acme and covers about three to four tenths of the area of the reef in this region. Nearly all other forms of coral are relatively rare in this region, although they may be common both nearer shore and near the outer parts of the reef-flat. Next to *Seriatopora*, the most abundant corals are *Porites*, *Acropora*, *Goniopora*, and *Euphyllia*. The bottom is hard and rocky with almost no coral sand. The living coral here is growing vigorously, very little dead coral being seen. The *Euphyllia* grows in crevices where it is protected from the waves.
1,200	8.5	Bottom hard and covered with broken stems of *Acropora*. The *Seriatopora* is still the dominant coral, but there are no large stocks and the coral is evidently broken by surges in time of storm, thus scattering small, detached, loose-lying stocks over the broken limestone bottom, which affords them a good lodgment, so that they continue to grow. There is very little sand upon the bottom here. The commonest corals are (in the order of their frequency) *Seriatopora*, *Porites*, *Pocillopora*, and *Acropora*—*Acropora* and *Seriatopora* being the most conspicuous; the nodular forms of *Porites* consist of numerous small heads.

TABLE 2.—*Depths of water and character of bottom along Line No. I of the southeast reef of Maër Island, Murray Islands, Queensland, Australia. The depths are those of the water at extreme low spring tides during September and October 1913*—Continued.

Distance from shore measured from mean high-tide line.	Depth of water. at low tide.	Character of bottom.
feet.	*inches.*	
1,400	14 5	Bottom hard and jagged with dead fragments of *Acropora*. The living stems of *Acropora hebes*, etc., project about 2 inches above low-tide level, but are all healthy and vigorous. Although *Acropora* is most conspicuous, it is not the commonest coral; the order of frequency is nodular *Porites*, *Seriatopora*, *Pocillopora*, and branching forms of *Acropora*. *Euphyllia* grows in protected crevices among the fronds of the *Acropora*.
1,600	9 5	The conspicuous corals are all rigid and thick-stemmed, thus enabling them to withstand the surge of the breakers which reaches them in time of storm. *Acropora palifera* is the most conspicuous coral, and *Acropora hebes* is next, but small heads of nodular *Porites* are much more numerous, although (being usually only 1 to 6 inches in diameter) they are not so conspicuous. The bottom is thickly covered with broken, wave-washed *Acropora*, and the heads of *Porites* and other solid forms are much cavernated. A few small stocks of *Seriatopora* grow in well-protected crevices among the *Acropora*. The corals in the order of their commonness are *Porites*, *Acropora*, *Pocillopora*, and *Goniastrea*. There is very little sand, and dead parts of all corals are cavernated.
1,725	Awash.	This is the region of broken, detached blocks of dead coral which have been torn from the Lithothamnion ridge and washed inward. These coral blocks are all small, not over 1 or 2 feet wide, the coral upon them being usually dead and the blocks covered with a green Spirogyra-like seaweed. These blocks project a few inches above low-tide level and are blackened like miniature "negroheads," which, indeed, they are. Corals do not thrive, being broken and disturbed by the wash of breakers and interfered with by seaweed which overgrows them.
1,780	8 inches *above* low-tide level.	This is about the middle of the elevated "Lithothamnion ridge," a relatively smooth, flat, wave-washed platform elevated about 6 to 8 inches above the level of the low spring tides. This so-called "Lithothamnion ridge" is composed of dead, compact coral covered with a veneer of *Nullipore algæ*, *Lithothamnion*, and *Bryozoa*. There are many living coral heads, even on the highest part of the ridge, all in small tide-pools and crevices, rarely more than 4 to 6 inches in depth and subjected to the almost constant wash of the breakers. All these corals are rigid, or massive forms clinging tenaciously to the bottom and sides of crevices and growing only on their sides, their upper parts being killed by exposure to the air at low tide, so they must spread out laterally. All *dead parts* of the coral are incrusted by Nullipore algæ and Bryozoa. The corals of these shallow tide-pools are thicker, stouter, and with stronger stems than are the stocks of the same species growing within 1,000 feet of the shore in calm regions of the reef-flat. This thickening is especially noticeable in *Pocillopora* and to a lesser degree in *Acropora;* and in these forms the branches tend to bend inward toward the shore, thus recalling the condition of trees upon a storm-swept coast. Corals which become dome-like heads on the inner parts of the reef-flat grow only into thin incrusting forms in these shallow tide-pools of the lithothamnion ridge. This so-called "lithothamnion ridge" is a solid mass of *dead coral* merely incrusted by lithothamnion, bryozoa, etc. *Goniastrea* is the commonest coral, with *Porites* and *Favia* next in the order named.
1,869	About 14 inches below low-tide level.	This is the outer edge of the reef which here falls off precipitously into water about 25 fathoms deep. From a depth of about a fathom and downward the steep outer wall of the reef is thickly covered with delicate foliated corals, such as certain forms of *Montipora*, but the constant breakers prevented a collection being taken in this region.

In order to determine the conditions of association and abundance of the various species of corals which grow upon the southeast reef-flat, squares 50 feet on the side were surveyed and their boundaries were marked by ropes secured by iron rods driven into the rocky floor of the reef-flat. Each of these squares was still further marked off by lines stretched from one side to that opposite, thus forming a "gridiron" pattern, 50 feet wide on each of the sides and with from 3 to 5 feet between the "crossbars." It was then a simple matter to count all coral heads in each alley-way between the cross-bars, and as each head was counted it was scarred by being struck with a crowbar, thus avoiding the probability of any head being counted twice.

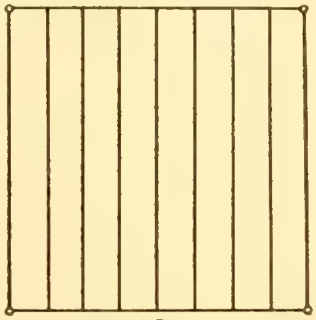

Fig. 5.—A 50-foot square laid out in crossbars.

The water being of crystalline clarity and the surface being usually but slightly rippled, no serious difficulty was experienced in counting and identifying the corals, although in some genera the more closely related species could not be distinguished one from another, and are thus grouped under the most probable specific name. This applies especially to *Acropora*, *Porites*, and *Favia*. The number of living heads on the 50-foot squares increases from 2 on the square 375 to 425 feet from shore to 1,838 on the square 1,400 to 1,450 feet from shore, this being about 200 feet shoreward from the inner wash of the breakers.

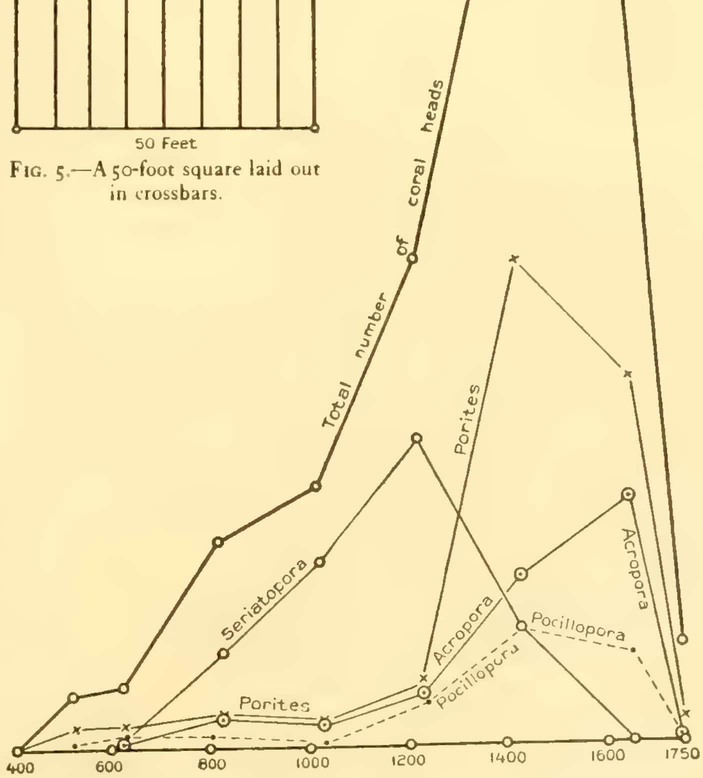

Fig. 6.—Illustrating table 3, showing the number of coral heads at each station on Line No. I across the southeast reef-flat of Maër Island.

Beyond this, toward the outer edge of the reef, the number of coral heads decreases, being broken in time of storm, but the *species* increase in number, becoming most numerous in the region of the inner surge of the breakers; even on the crest of the Lithothamnion ridge, which is laid bare for fully an hour at spring tides, there were 201 living coral heads on a 50-foot square.

The results are shown in table 3 and in text-figures 6 to 8.

TABLE 3.—*Number of living coral heads upon each of the nine 50-foot squares on Line No. I, across the southeast reef of Maër Island, Murray Islands, Queensland, in October 1913.* (See figs. 25 to 27, plate 16.) (For foot-notes see bottom of p. 25.)

Photo. No.[1]	Name of coral.	Distance (in feet) from the mean high-tide line of the shore.								
		375 to 425	500 to 550	600 to 650	800 to 850	1000 to 1050	1200 to 1250	1400 to 1450	1620 to 1670	1725 to 1775
41	Acrhelia horrescens (Dana)	...	...	...	...	2	...	...	...	...
8	Acropora (Isopora) palifera (Lamarck) var. a Brook	...	...	1	10	13	32	142	287	...
6	Acropora (Eumadrepora) hebes (Dana) and A. (Eumadrepora) pulchra Brook, etc	...	...	7	45	32	62	175	153	...
5	Acropora (Rhabdocyathus) murrayensis Vaughan	...	...	...	...	...	...	5	14	...
7	Acropora (Tylopora) digitifera (Dana)	...	...	...	4	1	4	19	49	2
36, 37	Astreopora ocellata Bernard	...	...	...	...	...	...	2	1	...
18	Cœloseris mayeri Vaughan	...	5	1	13	1	...	...	1	...
38, 39	Cyphastrea serailia (Forskål)	...	1	...	...	1	...	...	1	...
48	Euphyllia glabrescens (C. and E.)	...	1	...	1	22	19	27	...	...
31	Favites abdita (E. and S.)	...	...	...	...	...	...	1	7	14
28	Favites virens (Dana)	...	...	...	...	...	...	...	1	...
26	Favia pallida (Dana) f. 3 Vaughan	...	...	...	...	...	...	...	2	3
27, 30	Favia pallida (Dana) f. 6 Vaughan	...	...	...	...	1	...	...	6	23
29	Favia pallida (Dana) f. 4 Vaughan	...	...	...	...	...	...	4	3	2
	Fungia fungites (Linn.) and concinna Verrill	...	...	...	1	2	...	3	...	...
21, 22, 23	Goniastrea pectinata (Ehr.)	1	6	9	2	...	...	1	1	96
24, 25	Goniastrea retiformis (Lamarck)	...	1	...	...	1	1	2	26	...
17	Goniopora tenuidens (Quelch)	...	11	7	32	22	9	1	7	...
42	Hydnophora microconos (Lamarck)	...	...	...	...	...	...	...	2	1
33	Leptastrea purpurea (Dana) var.	...	...	...	...	...	...	...	6	1
34	Leptoria gracilis (Dana)	...	...	...	...	...	...	...	3	3
19	Mæandra astreiformis (M. Ed. and H.)	...	...	...	...	...	...	2	2	...
20	Mæandra dædalea (E. and S.)	...	...	...	...	...	...	...	3	4
47	Montipora sp. aff. informis Bernard	...	...	...	...	...	...	1	...	...
46	Montipora venosa (Ehrenberg)	...	...	...	...	...	...	12	4	1
45	Montipora ramosa Bernard. Not found on this reef-flat, but common on the other side of the island.									
32	Orbicella curta Dana	...	...	...	...	...	...	...	...	1
44	Pavona varians Verrill	...	...	...	5	...	...	...	1	...
1 to 3	Pocillopora bulbosa Ehrenberg	...	17	31	28	6	96	232	192	2
9 to 11, 12, 14, 13,15	Porites mayeri Vaughan, Porites murrayensis Vaughan, Porites australiensis Vaughan, and several other hemispherical or massive and nodular forms	2	47	48	68	47	129	973	735	47
16	Porites andrewsi Vaughan	...	20	16	13	7	...	...	...	...
43	Psammocora gonagra Klunzinger	...	1	...	...	...	...	...	...	...
4	Seriatopora hystrix Dana	...	...	6	191	371	610	236	4	...
40	Stylophora pistillata Esper	...	...	...	...	...	...	...	...	1
35	Symphyllia nobilis (Dana)	...	...	...	...	...	...	...	1	...
	Number of living coral heads on each 50-foot square	3	110	126	413	529	962	1,838	1,512	201
	Number of different species[2] on each square	2	11	9	13	15	9	18	26	15
	Distance of the center of each square, in feet, from the mean high-tide line of the shore	400	525	625	825	1,025	1,225	1,425	1,650	1,750

In the squares upon this reef-flat 24 genera of corals were found, yet 4 genera constitute 91 per cent of the total number of coral heads, thus: *Porites* 38 per cent, *Seriatopora* 25 per cent, *Acropora* 18 per cent, and *Pocillopora* 10 per cent.

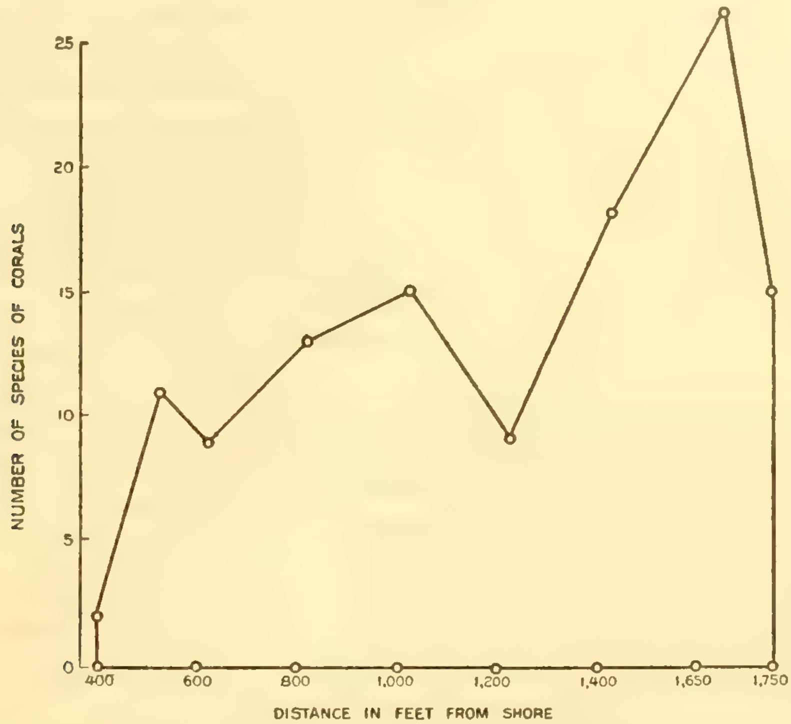

FIG. 7.—Illustrating table 3, showing number of kinds of coral at each station on Line No. I across the southeast reef-flat of Maër Island.

Figure 6 gives a graphic representation of the total number of coral heads on each 50-foot square at intervals of about 200 feet over the reef-flat. The increase is quite regular from about 400 feet from shore to 1,400 feet,

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Following references refer to table on opposite page:

[1]In photographs of Maër Island corals at the end of this paper, plates 12–19.

[2]The various forms of nodular or massive *Porites* allied to *Porites murrayensis* could not be specifically distinguished one from another excepting after more detailed study than could be given in this inspection of the living corals, and are therefore recorded as a single "species." This applies also to several of *Acropora* and *Favia*. Indeed, the specific identifications being made upon living forms must not be taken too literally, for it is often impossible to detect differences between clearly separated species until their skeletons are studied in detail. Thus I record only 39 species from Line No. I, whereas in collections made along this line, and within 200 feet on each side of it, Vaughan records 62 species.

The square 1,725 to 1,775 feet from shore is on the crest of the Lithothamnion ridge about 4 to 6 inches *above* low-tide level of spring tides. The corals here are all small, stunted stocks clinging to the shallow crevices in the breaker-washed tide-pools. When branched, the branches are thick, short, and most of them bend *inward* toward the shore.

The inner wash of the breakers makes a fairly strong current in the square 1,620 to 1,670 feet from shore and many of the corals are broken, but in this region the coral life is most varied in *species*, there being 26 kinds of corals as opposed to 18 in the region where the *coral heads* are most abundant.

The 1,400 to 1,450 foot square is in relatively calm water about 200 feet inward from the innermost surge of the breakers, and it is here the coral heads attain their acme of development, although there are more *species* or corals about 1,600 feet from shore where the wash of the breakers is strong.

The relative scarcity of most of the species of corals upon the square 1,000 to 1,050 feet from the shore is due to the great development of large stocks of *Seriatopora hystrix*, for this coral alone covers about 40 per cent of the area of the square, and constitutes 70 per cent of the total number of coral heads in this region.

In the square 1,200 to 1,250 feet from shore the *Seriatopora* is even more numerous but the stocks are generally small and broken by waves and do not cover more than 20 per cent of the area of the square.

but beyond 1,600 feet there is a rapid falling off because the crest of the lithothamnion ridge is laid bare at low tides.

On the square whose center is 1,650 feet from shore there are 1,512 coral heads, whereas there are 1,838 coral heads on the square whose center is 1,425 feet from shore, thus showing that coral heads do not survive so well in the breakers as in somewhat more quiet water. A greater number of species of coral are, however, found in the region of the breakers than anywhere else upon the reef-flat, while in the less agitated water nearer shore

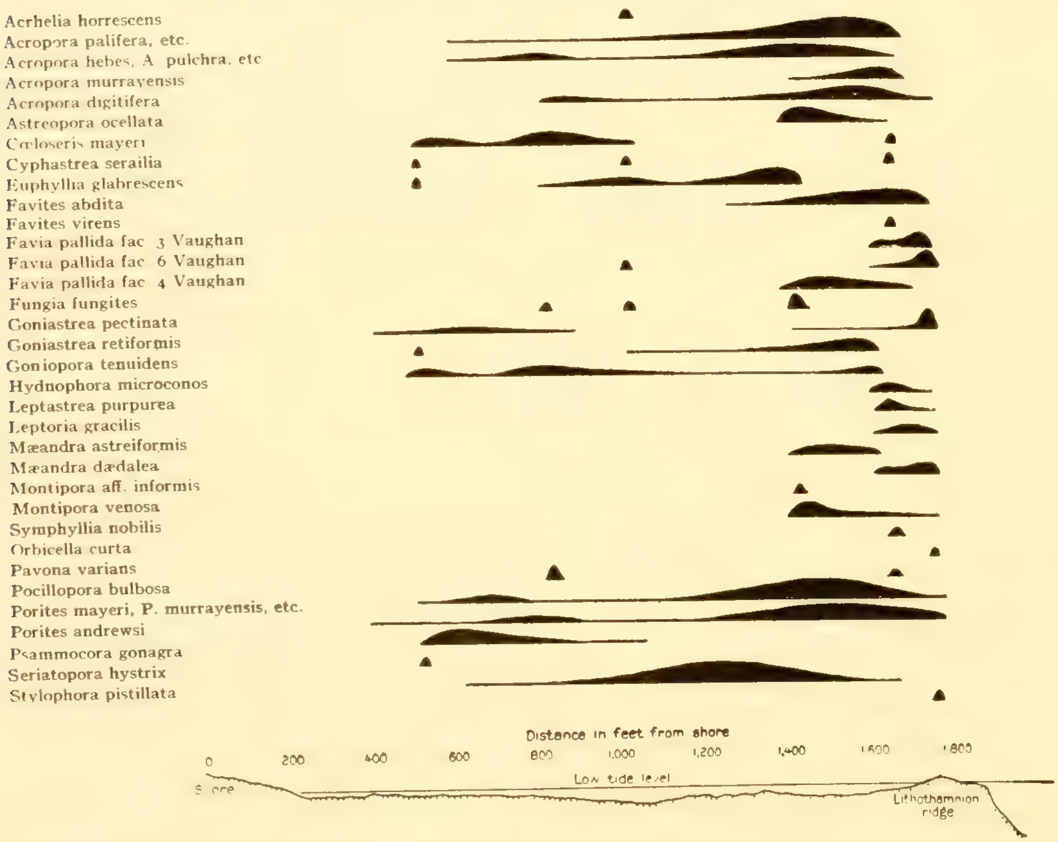

FIG. 8.—Diagram showing the range of each species of coral along Line No. I across the southeast reef-flat of Maër Island.

the coral heads are larger and more numerous but the number of species is not so great. Thus, on the square whose center is 1,425 feet from shore, where coral heads are most densely clustered, there are but 18 kinds of coral; whereas in the breakers 1,650 feet from shore there are 26 species of corals, 8 being peculiar to this region alone, although the coral heads are here less numerous and are broken by the rushing water. The cause of this may be that in the breakers where the coral heads are small and not densely crowded their struggle for existence is mainly with the sea and not with one another,

whereas in the less agitated water there is abundant evidence of a severe struggle between various forms for mastery. Thus, in the mid-region of the reef-flat *Seriatopora* crowds out a number of species which appear both shoreward and seaward of this region, and all other species are reduced in numbers where *Seriatopora* is most successful. The surges can not destroy the small heads which are sheltered in crevices, but on the contrary the agitated water must bring to them a good supply of pelagic animals for food. Thus, Wood Jones is perhaps somewhat misleading when he asserts that the region of the breakers is relatively deficient in coral life. However, at a distance of about 1,725 feet from shore, where the lithothamnion ridge is most broken and pounded by the surf, corals do not thrive well, possibly owing to the extensive growth of a Spirogyra-like seaweed upon the rocks. It will be recalled that in 1878 the corals in parts of the lagoon of Cocos-Keeling were destroyed by water from a supposed volcanic vent, and Wood Jones observes that the coral growth in these regions has not reappeared even after thirty-four years. Wood Jones attributes this failure to the growth of a Spirogyra-like seaweed. Curiously, a parallel case occurred at Tortugas, Florida, where *Acropora* (which once grew in abundance in the lagoon) was killed by the "dark water" of October 1878,[1] and has not yet (1917) renewed its dominance, only an occasional small cluster being here and there found in the shallow waters of the lagoon where once the patches covered acres in area. Thus corals which were once the dominant species may, if destroyed, be unable to reassert their supremacy even after thirty-nine years. But the author is inclined to believe that causes other than the growth of seaweed have prevented *Acropora* from reappearing in the lagoon at Tortugas.

Where the corals struggle mainly against an adverse environment the heads are widely separated but are of many species; but where the environment is favorable and the struggle is chiefly between coral and coral, the heads are closely crowded, but the kinds that can survive are few. One seems to see this law illustrated upon a grand scale in the many individuals of few kinds which crowd the cold waters of temperate and subpolar seas where the plant-food is abundant and the temperature near an optimum for vital processes. In the tropical oceans, on the contrary, the plant-food is deficient and the temperature is close to the danger-point, and here in this relatively unfavorable environment individuals are rarer than in cold seas, but the number of species is far greater.

It will be recalled that Duerden, 1904,[2] found that corals require animal food in considerable quantity, and Vaughan, 1912,[3] showed that their food is exclusively animal, and that they do not devour phyto-plankton. One might suppose, therefore, that the gradual decline in the number of coral

[1]Jefferson, J. P., J. Y. Porter, and T. Moore, 1878, Proc. U. S. Nat. Mus., vol. 1, pp. 244–246.
[2]Duerden, J. E., 1904, The Coral *Siderastrea radians*, Carnegie Inst. Wash. Pub. No. 20, p. 5.
[3]Vaughan, T. W., 1912, Carnegie Inst. Wash. Year Book No. 11, pp. 159–161.

heads per unit area, as one goes inward from the 1,400-foot station toward shore, is due to a corresponding decline in the food supply, the more favored corals on the outer parts of the reef-flat devouring most of the pelagic and other food-animals. But in his study of the Florida corals in 1912 Vaughan pointed out the fact that the fleshy parts of well-fed corals appear plump and distended, while those of starving corals are drawn and thinly spread over the skeleton; and judging by this criterion, it seems that the corals near shore are quite as well supplied with food as are those farther out on the reef-flat. This leads one to suspect that the food supply is everywhere more than sufficient for the corals, but the case should be tested by making observations upon the growth-rate of corals near shore and far out upon the reef-flat, and also quantitative studies should be made of the plankton at various states of the tide and at different distances from shore. Unfortunately, these studies were not attempted at Murray Island, the duration of our stay there being too short to render the results of such an investigation reliable.

Considering the zone of reef-flat which is 1,150 feet wide and lies between 500 and 1,650 feet from shore, there are on an average 785 living corals on each 2,500 square feet, and thus upon the 2 miles of reef-flat there are probably 3,600,000 coral heads.

Despite the large quantity of zoöplankton required to provide these corals with food, it seems that conditions other than the supply of nourishment are probably responsible for their decline in number as we go inward from the 1,400-foot station toward the shore.

It will be recalled that Gardiner was of the opinion that corals might be nourished in some measure by their commensal plant cells, and certainly, as Vaughan has observed, reef corals do not thrive in shaded places, under docks, etc., although only a few feet distant, where sun-light is able to penetrate, they may flourish in abundance. In order to test this matter, Vaughan[1] placed 18 species, representing practically all the important reef corals of Florida, in a submarine dark chamber for 43 days. At the end of this time most of the corals were decidedly bleached, owing to the death of their plant-cells, but in only 5 species did the corals themselves die. This would lead one to suppose that the plant-cells are not so essential to the life of the reef corals as has often been supposed. Certainly they do not directly supply nourishment, for corals refuse all plants as food. Corals, however, are not the only cœlenterates which are independent of their commensal plant-cells for food, for the scyphomedusa *Cassiopea*, if kept in the dark for more than a month, loses most of its infesting zoöxanthellæ and yet lives apparently as well as ever, and Whitney demonstrated that *Hydra* if deprived of its green algal cells lived quite as well as if they were present.

The coral reefs of the Murray Islands are among the richest of the entire Barrier Reef. Being 70 miles from the New Guinea coast, they are removed

[1]Vaughan, T. W., 1914, Carnegie Inst. Wash. Year Book No. 13, p. 225.

from the mud which pours into the ocean from the Fly River region and which prevents the growth of corals and keeps open the wide Bligh Entrance. Moreover, being within 6 miles of the outer edge of the Great Barrier plateau, the southeast trade wind drives water from the open Pacific upon their shores. We know of no richer region than the Murray Islands for littoral Echinoderms,[1] and many types of mollusks are abundant among the coral reefs; yet there are no large coral heads to be found upon the reef-flats which surround these islands.

At Thursday Island, where silt interferes seriously with the coral reefs, the corals are more widely separated, but the heads are larger than at the Murray Islands, and this is also true of the reefs between Townsville and Cairns, where hurricanes are a disturbing factor; yet at the Murray Islands, where conditions appear to be ideal for coral growth, we find only small heads thickly clustered over the reef-flats instead of large ones more or less widely isolated, as in other parts of the Great Barrier Reef. It seems possible that in a hurricane region the large and firmly anchored stocks may gain an advantage over the smaller ones in that they alone can survive the effects of such storms and may thus be free to fill the space once occupied by the many small coral heads which formerly grew around them; also on reefs subject to silting, the small heads must suffer more seriously than the large.

Small living stocks of organ-pipe coral, *Tubipora*, were found on the southeast reef of Maër Island between 1,000 and 1,400 feet from shore, but they were rare both shoreward and seaward of this region, and being everywhere few in number were not an important constituent of the reef.

No Millepores were seen upon the southeast reef-flat, and they were rare elsewhere among the Murray Islands. The fleshy Alcyonaria, such as *Sarcophyton*, appear to be less sensitive to the injurious influences of silt than are the Madreporean corals, and are the dominant forms off the western corner of the island, being also common off the sandy northwest shore, but rare on the wide southeast reef-flat, where there is little silt and the pure ocean water is being constantly driven in over the reef by the southeast wind.

When we come to study the distribution and association of the various species of corals found on the southeast reef, we find that each species thrives best at some definite distance from the shore. Some, indeed, are restricted to zones extending neither to the shores nor to the outer edge of the reef. Such for example are *Porites andrewsi* Vaughan, which is found only between 450 and 1,100 feet from shore, and *Seriatopora hystrix*, which is confined to a region between 600 and 1,650 feet from shore.

An inspection of table 3 shows that of the 24 genera of corals from the squares across the southeast reef-flat only 3 extend entirely across the flat from 500 feet out to the tide-pools on the crest of the lithothamnion ridge, 1,775 feet from shore. These 3 are nodular forms of *Porites*, *Pocillopora*,

[1]Dr. H. L. Clark collected 151 species by wading in the shallow waters near the shore of Maër Island.

and *Goniastrea.* The *Porites* and *Pocillopora* reach their maxima at 1,400 to 1,450 feet from shore, and *Goniastrea pectinata* and *retiformis* are the dominant corals of the crevice-like tide-pools of the lithothamnion ridge.

The mode of distribution and frequency of occurrence of the various species of corals over the southeast reef are shown diagrammatically in figures 6 to 8, and the significant fact is that, with the *exception* of *Seriatopora hystrix*, all the other species are reduced in numbers near the middle of the reef-flat at about 1,100 feet from shore. This, indeed, is the region in which *Seriatopora hystrix* attains its acme and covers about 40 per cent of the area of the reef and constitutes 70 per cent of the coral heads, thus crowding out the other species. It is a clear illustration of the struggle for existence between the various species of corals.

About one-half of the species of the reef-flat are confined to the outer zone between 1,000 feet from shore and the seaward edge of the reef, while of the abundant forms only two, *Porites andrewsi* Vaughan and *Cœloseris mayeri* Vaughan are shore corals, being practically confined to within 1,100 feet of the beach.

No corals were found growing *in situ* within 440 feet of the shore, the three coral heads found on the square 375 to 425 feet from shore having been driven shoreward on loose blocks of limestone in time of storm.

In general, it appears that each of the common corals attains a well-defined maximum at some definite distance from shore and declines in frequency both shoreward and seaward of this most favorable locality. In order to find the reason for this one must determine the physical factors of the environment at different places over the reef-flat and with this in view a series of temperatures were taken at various states of the tide and times of the day.

EXPERIMENTS UPON TEMPERATURE.

Table 4 presents the details and table 5 a summary of the observations of the temperature of the water of the reef-flat and of the air close to the surface of the water.

TABLE 4.—*Temperatures of the air over the reef and of the water on Line No. I across the Southeastern reef of Maër Island, Great Barrier Reef, Sept. 30 to Oct. 23, 1913.*

Date.	Condition of tide, wind, etc.	Distance from the shore, measured from mean high-tide line.	Depth of water.	Temperature. Air.	Temperature. Water.	Temperature. Difference. Water warmer than air +; cooler than air −.
1913 Sept. 30..	Stiff southeast breeze 15 to 20 miles per hour.					
p. m.		*feet.*	*inches.*	C°	C°	C°
$2^h\ 32^m$	Water receding, near low water of new moon spring tide.	200	4	27.5	31	3.5+
2 40	...Do	400	4.5	27	30	
2 44	....Do	600	6.5	26.5	29	3 +
2 56	....Do	800	10.25	26	28.5	2.5 +
3 08	....Do	1,000	16.25	26	28.5	2.5 +
3 14	....Do	1,200	8.5	26.25	28.5	2.5 +
3 25	....Do	1,400	14.5	26.2	28	2.25+
3 36	Time of lowest water	1,600	9.5	26	28	1.8 +
3 44	Tide coming in, water rising	1,800	4	25.5	27.5	2 +
3 50	....Do	1,800 in breakers at outer edge of reef.	24 ±	25.5	25.5	2 + 0
5 00	....Do	200	6 ±	26.5	27	
5 06	....Do	400	6 ±	26.2	27.5	0.5 +
Oct. 3....	Sun just risen, low tide, southeast breeze of about 15 miles per hour blowing all night. Intermediate tide, neither neap nor spring.					1.3 +
a. m.						
$6^h\ 10^m$	....Do	200	4	25	22	
6 17	....Do	400	4.5	25	22.5	3 −
6 22	Tide about lowest	600	7	24.5	23	2.5 −
6 43	Tide beginning to rise	1,200	9.25	25	23	1.5 −
7 00	Tide rising	1,860 in breakers.	24 ±	25	25	2 − 0
Oct. 4....	Low tide. A southeast breeze of about 15 miles per hour blowing all night.					
a. m.						
$6^h\ 37^m$	Low tide, about the lowest	400	4.75	25	24.4	2.6 −
7 35	Tide coming in	800	12.5	24.4	23.1	1.3 −
Oct. 9....	Southeast breeze about 8 miles per hour. Neap tide came Oct. 7.					
p. m. $12^h\ 45^m$	Low tide	200	4.5±	27.8	34.5	6.7 +
Oct. 15...	Spring tide of full moon. Gentle east breeze.					
p. m.						
$3^h\ 50^m$	Tide beginning to rise	1,700	......	26.4	25.6	0.8 −
4 22	Tide rising	100	6 ±	26.2	30.4	4.2 +
Oct. 16...	Flat calm. Water receding, low at about 4 p. m. This tide was fully as low as the spring tide of yesterday.					
p. m.						
$2^h\ 48^m$	Tide receding	100	6 ±	26.8	33.4	6.6 +
2 55	....Do	850	18 ±	26.4	29	2.6 +
3 05	Tide about low	1,620	12 ±	26.2	28.8	2.6 +
4 34	Tide coming in	400	5.5	26.4	29.2	2.8 +
4 37	....Do	100	6 ±	26.7	30.8	4.1 +

TABLE 4.—*Temperatures of the air over the reef and of the water on Line No. I across the Southeastern reef of Maër Island, Great Barrier Reef, Sept. 30 to Oct. 23, 1913*—Con.

Date.	Condition of tide, wind, etc	Distance from the shore, measured from mean high-tide line.	Depth of water.	Temperature.		
				Air.	Water.	Difference. Water warmer than air+; cooler than air−.
1913 Oct. 17...	Calm water hardly rippled by a slight northwest drift of air. Water receding, low at about 4h 30m p. m.					
p. m. 2h 47m	Water receding	100	4 ±	28.8	34.2	5.4 +
2 55	....Do	400	6 ±	27	29.4	2.4 +
3 02	....Do	600	9 ±	27	28.9	1.9 +
3 10	....Do	1,200	12 ±	27.4	28.8	1.4 +
3 17	....Do	1,600	12 ±	27.2	28.4	1.2 +
3 24	....Do	1,860 in breakers.	24 ±	27.2	28.4	1.2 +
5 05	Tide coming in	1,600	......	26.8	28.5	1.7 +
5 14	....Do	1,200	......	27.4	28.75	1.35+
5 21	....Do	600	......	26.6	28.8	2.2 +
5 25	....Do	400	......	26.4	28.8	2.4 +
5 31	....Do	100	......	26.1	29.3	3.2 +
Oct. 19...	Intermediate tide neither neap nor spring. Sun just risen. Strong breeze from southeast blowing at about 20 miles an hour all night.					
a. m. 6h 12m	Tide at about its lowest	100	3 ±	24.7	23.3	1.4 −
6 22	Tide beginning to rise	400	7.5	24.7	.3.8	0.9 −
6 30	Tide coming in	600	9 ±	24.7	23.9	0.8 −
6 40	....Do	1,200	11.5±	25.2	24.6	0.6 −
6 50	....Do	1,600	14 ±	25.6	24.85	0.85−
6 58	....Do	1,860 in breakers.	12 ±	25.2	24.9	0.3 −
Oct. 22... 12 noon	Tide half flood. Tide coming in, 10-mile southeast breeze.	100	......	27	29.95	
Oct. 23...	Neap tide of moon's last quarter. Tide had been coming in for the past 4 hours. Southeast breeze of about 10 miles per hour.					
p. m. 3h 00m	....Do	10± Very near shore.	24 ±	28.7	34.8	6.1 +

TABLE 5.—*Summary of temperature of air and of water observed at various times of the day and of stages in tide over southeast reef of Maër Island, Great Barrier Reef, Sept. 30 to Oct. 23, 1913.*

Distance out from shore.	Temperature of water.			Temperature of air.		
	Highest.	Lowest.	Range.	Highest.	Lowest.	Range.
feet.	*°C.*	*°C.*	*°C.*	*°C.*	*°C.*	*°C.*
200	34.5	22	12.5	27.8	25	2.8
400	30	22.4	7.6	27	24.7	2.3
600	29	23	6	27	24.5	2.5
800	29	23.1	5.9	26.4	24.4	2
1,200	28.8	23	5.8	27.4	25.0	2.4
1,600	28.8	24.85	3.95	27.2	25.6	1.6
1,660 in the breakers at outer edge of reef	28.4	24.9	3.5	27.2	25.2	2

The extreme range observed in air temperature 200 feet seaward from the shore between September 30–October 23, 1913, was 2.8° C., while the extreme range of water temperature for the same times and place was 12.5° C. Early in the morning the water near shore was 0.9° to 3.0° cooler than the air, whereas in the hottest part of the afternoon it was 4.2° to 6.7° warmer than the air. Thus, over this reef-flat solar radiation, not air temperature, is the chief factor in warming the water during the day, and during the night the chief factor in cooling the water is radiation from the surface of the water into outer space, not convection of heat by the cooling air.

The results of these temperature observations are shown in graphic form in figure 9.

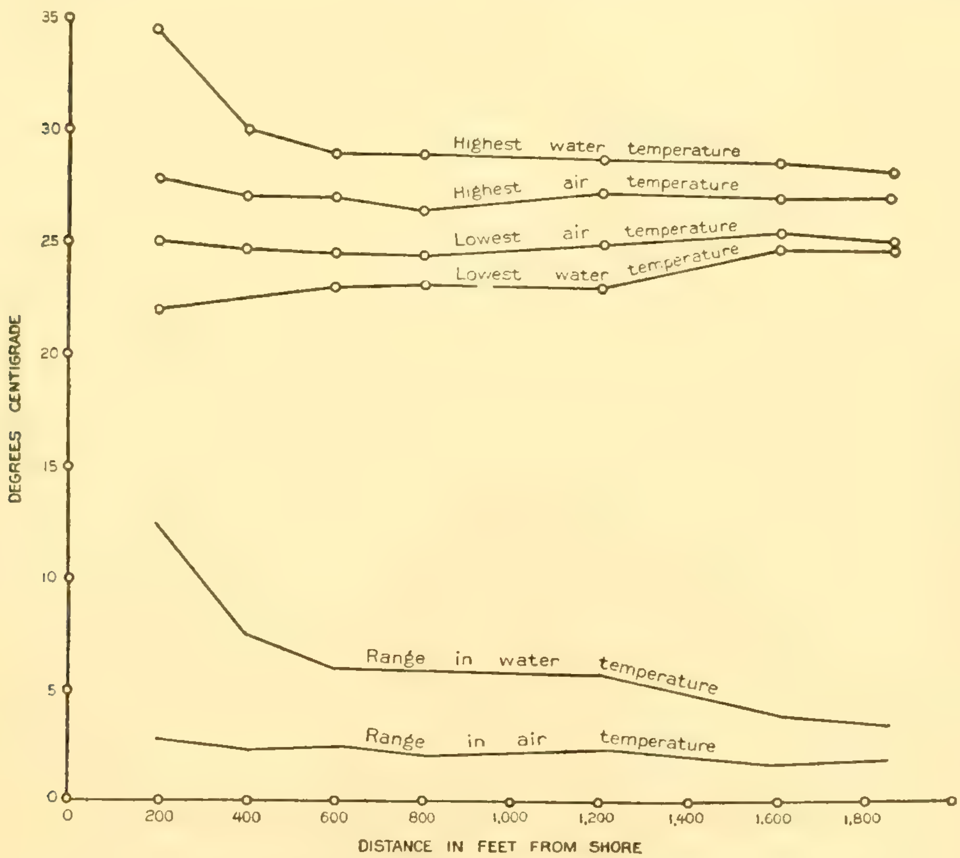

FIG. 9.—Showing the temperatures and the range in temperature of the water and of the air over the water along Line No. I on the southeast reef of Maër Island.

It appears that while the surface of the sea outside the reef ranges through 3.5°, the range over the reef-flat is greater than this and increases as one approaches the shore, becoming 12.5° near the beach. Moreover, in the hot calms of the northwest season in January, the temperatures over the reef-flat must be considerably hotter than those observed during the cool days of October, and it seems probable that the heat alone would be sufficient to kill all corals within 450 feet of the shore, for, according to Mr.

John S. Bruce,[1] Government meteorologist, the average air temperature at 2 p. m. during December 1914, was 35° C.

Corals were placed on the hot sand beach in glass aquaria, the water within which was heated slowly by being exposed to the sun's rays, or over a spirit lamp.[2] Three or four hours were required to raise the temperature to the highest point, after which the coral was replaced in the ocean and observed on the following day to determine whether it survived or not. The results are recorded in table 6.

TABLE 6.—*Upper temperature-limits which Maër Island corals can survive.*

Name of coral.	Survived without apparent injury.	Visibly injured but survived.	Killed.
	°C.	°C.	°C.
Seriatopora hystrix	35.9	....	35.8 to 36.3
Pocillopora bulbosa	36.1	36.3 to 36.9	35.8 37.1
Acropora palifera	35.6 to 36.4	....	36.2 36.5
Goniastrea pectinata	36.3	....	36.2 37.2
Goniopora tenuidens	36.4	....	....
Euphyllia glabrescens	....	....	36.3
Cœloseris mayeri Vaughan	36.8	37.5	38
Porites mayeri Vaughan	37.2	37.2	37.2
Porites andrewsi Vaughan	37.3	....	35.8 to 37.3

It appears that *Seriatopora hystrix*, *Acropora palifera*, and *Euphyllia glabrescens* are killed below 37° C., and these are all corals of the outer parts of the reef-flat and do not flourish within 500 feet of the shore. On the other hand, *Cœloseris mayeri* Vaughan, *Goniastrea pectinata*, and the various forms of *Porites* are resistant forms, most individuals having death temperatures of 37° C. and higher, although occasionally an individual colony dies at about 36°, but this is quite exceptional and these species are the only corals which flourish within 500 feet of the shore.

It seems, then, that the water within 550 feet of the shore becomes too hot for certain corals[3] and this factor alone may possibly suffice to account for these corals being confined to the seaward parts of the reef-flat. It is interesting to record that these Pacific corals are not more resistant to high temperature than are the corresponding genera of the Florida reefs.[4]

At Thursday Island a death temperature due to cold for several species of corals was determined with the results shown in table 7.

[1]Mr. John Stewart Bruce states in a letter that the mean shade temperature of the air under a large tree near the shore on the northwest side of Maër Island averaged 31.1° C. in December 1913 and 31.6° C. in both January and February 1914. In 1914 the average maximum temperature ranged from 35° in December to 28.3° in July and August.

[2]The author has always been mindful of the time-factor in these temperature studies (Crozier, 1916, to the contrary) and the sea-water was heated at the rate of 2° C. per hour, as was also done in the study of the temperature range of Florida Corals, and thus the Australian observations are comparable with those made in Florida (see p. 20, Carnegie Inst. Wash. Pub. No. 183, 1914).

[3]The critical temperature is that at which the corals lose their ability to capture or retain food, and we find that this in *Mæandra areolata*, *Acropora muricata*, and *Siderastrea radians* of the Atlantic ranges from 1.5° to 3° C. below their death temperatures for heat.

[4]See Mayer, 1914, Papers from the Tortugas Laboratory of the Carnegie Institution, vol. 6, p. 19, table 6; Carnegie Inst. Wash. Pub. No. 183.

The author also made some experiments upon the corals of Porto Rico and of Tortugas (Florida) and found that upon gradually cooling the sea-water within which hungry reef corals are living they gradually lost their activity and with it their ability to capture food (crab or snail meat). Food *already captured*, however, could be held upon the surface of the tentacles or other parts to within 1° C. of the death temperature, whereas the corals lost the power to seize fresh pieces of crab meat at about 3° to 5° C. above the death temperature for cold.

TABLE 7.

Name of coral.	Temperature which the coral survived without apparent injury.	Temperature survived, but with apparent injury.	Temperature which killed the coral.
Pocillopora bulbosa	14.4 to 15.3° C. for 5 hours. In another experiment this species was cooled to 9.6° in 45 minutes and survived.	13.4 to 14.2° C., generally at about 13.6° for 5 hours. This nearly killed the coral.	
Acropora digitifera	....	....	13.4 to 14.2° C. for 5 hours.
Cœloseris mayeri Vaughan	13.4 to 14.2° C., usually at 13.6° for 5 hours. It also survived being cooled to 9.6° for 45 minutes.		
Porites mayeri Vaughan	13.8 to 14.8° C., usually at 14.7° for 4½ hours.		
Goniastrea pectinata	13.8 to 14.8° C., usually at 14.7° for 4½ hours.		

Table 8 shows the extremes for a number of determinations upon different individual coral stocks, each coral being held for 1 hour at the temperature stated. Thus, after one hour at about 61° F., or 16° C., most of the reef corals would be unable to capture food, and doubtless a sustained exposure to 18.5° C. would be fatal if from no other cause than that it would result in starving the corals.

TABLE 8.

Name of coral.	Temperature at which food can no longer be captured.
	° C.
Siderastrea radians	10.5 to 17.3
Porites furcata	14.5 14.7
Acropora muricata	17.4 17.8
Mæandra areolata	16.3 18.6

It would seem that Australian corals, which are never called upon in nature to withstand the effects of cold, are about as able to resist low temperatures as are the corresponding genera of Florida.[1] This is interesting, for nearly every winter the Florida corals are brought close to their death temperature by the cold northerly storms, and yet natural selection has not enabled them to attain an increased resistance to cold. Similarly, the Australian corals, which are annually called upon to withstand a higher temperature than are those of Florida, are not more resistant in this respect than are Florida corals. The whole matter of temperature resistance is physiological and natural selection appears to have had nothing to do with improving it.

[1]See Mayer, A. G., 1914, Carnegie Wash., Researches from the Tortugas Laboratory, vol. VI, p. 19.

EXPERIMENTS UPON THE EFFECTS OF SILT ON CORALS.

The fact that corals which are sensitive to high temperature do not occur within 500 feet of the shore, while those which can survive the heat do occur in this region, suggests that temperature is the controlling factor, although there may be others which operate in conjunction with or independent of temperature and which would themselves suffice to prevent the growth of corals in this region. For example, in time of rain or during storms a considerable quantity of silt becomes stirred up from the bottom and mud is also poured out over the reef-flat from the steep slopes of the island, and this may be a determining factor in checking the growth of corals within 500 feet of the shore. Accordingly, tests were made aiming to determine the ability of the various common reef-flat corals to resist silt, the corals being buried about 2 inches under the fine limestone mud covering the floor of the reef-flat. The results are stated in table 9.

TABLE 9.—*Experiments upon burying corals 2 inches under the mud of the reef-flat, the water over the mud being 6 inches deep at low tide.*

Name of coral.	Duration of burial.				
	$14\frac{1}{2}$ hours.	24 hours.	$39\frac{1}{2}$ hours.	46 hours.	48 hours.
Seriatopora hystrix	Killed				
Pocillopora bulbosa	Do				
Acropora hebes	Do				
Acropora palifera	Do				
Goniastrea pectinata		Apparently uninjured.	Living		Nearly killed.
Goniopora tenuidens	Injured but survived.		Two-thirds killed.		Killed.
Euphyllia glabrescens		Killed			
Cœloseris mayeri Vaughan		Lived apparently uninjured.		Two-thirds killed.	Killed.
Fungia aff. fungites (Linn.)		Apparently uninjured.	Nearly killed.	Nearly killed.	
Mæandra astræiformis			Killed		
Porites mayeri Vaughan	Apparently uninjured.	3 lived; 2 killed	Killed	Nearly killed.	
Porites andrewsi Vaughan		Badly injured, but lived.	Killed		
Montipora ramosa		Usually killed			

It appears that the corals which are confined to the seaward parts of the reef-flat beyond 500 feet from shore are those which can not withstand being covered with mud for $14\frac{1}{2}$ hours, whereas the dominant inshore corals can still survive after being buried for 24 hours beneath the mud. Thus, *Seriatopora hystrix*, *Pocillopora bulbosa*, *Acropora hebes*, and *A. palifera* are very sensitive to the smothering effects of silt and these are all off-shore forms.

On the other hand, *Porites andrewsi* Vaughan, *P. mayeri* Vaughan, *Cœloseris mayeri* Vaughan, and *Goniastrea pectinata*, which are the dominant forms close to the shore, can usually withstand being covered with mud for 24 hours.

We may therefore assert that the off-shore corals, those which can not live within 500 feet of the beach, are forms which are sensitive both to high

temperature and to the effects of silt. They must have clean, cool water in which to live. Only forms which can withstand both high temperature and muddy water can live within 500 feet of the shore. This suggests that high temperature may produce death through asphyxiation and, as is well known, Winterstein[1] concluded that heat depression in frogs is a form of fatigue due to the oxygen being insufficient to support the accelerated metabolism of the animal.

Doubt has been cast upon this conclusion by Babák[2] and by Amerling,[3] who showed that certain frogs which are resistant to heat paralysis are easily paralyzed by lack of oxygen, while others (such as *Rana fusca*) are resistant to lack of oxygen but readily paralyzed by heat. Finally, Becht[4] found that in the isolated cord, and in the isolated nerve of frogs, and in the automatic ganglion of the *Limulus* heart, recovery from heat paralysis can take place in the absence of atmospheric oxygen. There may, however, be sufficient oxygen generated in the tissues to cause recovery. See Carlson.[5]

TABLE 10.—*Death temperatures and relative resistance to asphyxiation in various species of corals from the Bahamas and from Florida.*

Name of coral.	Death temperature.	Time required to kill coral if buried under mud.
	° *C.*	*hours.*
Acropora muricata	35.8 to 37, usually at about 36.5.	10
Orbicella annularis	36.8	19
Porites clavaria	37.7	24
Porites astreoides	37.7	24
Favia fragum	37.2	About 45 hours.
Mæandra areolata	36.7 to 37.2	72
Siderastrea radians	38.5	More than 73.

In view of this conflict of results, experiments were conducted upon corals from the Bahamas and the Tortugas. It was found that those corals which are resistant to being smothered under the mud are correspondingly resistant to the effects of carbon dioxide in the sea-water.

Thus, *Acropora muricata* is least resistant and is killed by being buried 10 hours under the mud, whereas *Siderastrea radians* is the most resistant coral and is only about half killed by being buried 73 hours. The death temperatures of various Atlantic corals and their relative ability to resist smothering by mud or asphyxiation by CO_2 is given in table 10.

Vaughan several years ago observed that *Siderastrea radians* and *Mæandra areolata* were corals of the inner flats where the bottom was apt to be muddy; on the other hand, *Acropora muricata* requires pure water in a

[1]Winterstein, 1902, Zeit. für allgemeine Physiologie, Bd. 1; *also* Bondy, 1904, *Ibid.*, Bd. 2; *also* Verworn, 1913, Irritability, pp. 240–243.
[2]Babák, 1907, Centralblatt für Physiol., Bd. 21, pp. 6–8.
[3]Amerling, 1908, Pflüger's Archiv für Physiologie, Bd. 121, pp. 263–269.
[4]Becht, 1908, American Journal Physiol., vol. 22, pp. 456–476.
[5]Carlson, 1906, American Journal Physiol., vol. 15, p. 232.

situation protected from the full force of the breakers. We now find that *A. muricata* is very sensitive to heat and correspondingly so to the smothering effects of silt, and it is interesting to see that Dr. Shiro Tashiro found upon testing these corals in his "biometer," which detects very minute amounts of CO_2, that the metabolism as measured by CO_2 production in *Acropora muricata* is much more rapid than in the "mud coral" *Siderastrea radians.*

In general, table 10 seems to indicate that the more resistant a coral is to asphyxiation the higher its death temperature, but *Favia fragum* and *Mæandra areolata* have lower death temperatures than one would expect from their very considerable resistance to asphyxiation.

A clew to an explanation of this matter appears, however, if we heat the corals while they remain buried under the mud. Under these conditions, *Acropora*, *Orbicella*, and *Porites* die at temperature 0.4° to 0.1° C. lower than if heated in open sea-water; but *Favia*, *Mæandra*, and *Siderastrea* withstand heat when buried about as well as they do if in the open sea. It seems, then, that *Favia*, *Mæandra*, and *Siderastrea* can live at a reduced rate of metabolism, and being buried puts them into a condition resembling hibernation in which heat has but little power to raise the rate of their vital processes. On the other hand, the pure-water corals *Acropora*, *Orbicella*, and *Porites* have little or none of this capacity for adjustment but must maintain a nearly constant rate of metabolism. Thus heat becomes more effective in killing them if partially smothered by the mud than if they be in pure open water.

If this explanation be valid, Winterstein's explanation of the manner in which heat depression is produced may be correct. In order to test this matter more fully, however, experiments should be conducted upon some animals which do and others which do not hibernate and their rates of metabolism at various temperatures and under various conditions of oxygen-supply should be quantitatively determined.

But to return to the discussion of the corals of Maër Island, *Montipora ramosa* does not occur on the southeast reef, but it is the dominant coral of the inshore muddy grass-flats on the middle of the northwest side of the island, where it often completely covers areas hundreds of square feet in extent. If buried beneath the mud for 24 hours it is usually killed, although it can occasionally survive this treatment, but with serious injury. It seems, however, that this coral is protected from the mud by the roots of the sea-grass, *Posidonia*, which grows in association with it and which binds the mud together and tends to prevent its being churned up into silt. Thus, *Montipora ramosa* is often laid bare for 2 hours or more at the low spring tides. Experiments show, however, that being soft and porous it absorbs water from the moist mud around it and this enables it to survive. If dried in the sun without permitting its basal parts to rest in water, it is nearly killed by being exposed for $1\frac{1}{2}$ hours to sunlight, the dry-bulb temperature being 30.35° C. and the humidity 83.5 per cent.

EXPERIMENTS UPON DILUTION OF SEA-WATER.

Another factor which might be supposed to affect the welfare of the inshore corals of the southeast reef is dilution of the sea-water during the showers of the rainy season, from November to May.[1] Table 11 shows the results obtained by placing corals in large aquaria in sea-water diluted 50 per cent by mixing it with an equal volume of rain-water.

TABLE 11.—*Results obtained by placing corals in 50 per cent sea-water, made by diluting sea-water with an equal volume of fresh (rain) water.*

Name of coral.	Duration of experiment.		
	$4\frac{1}{2}$ hours.	$11\frac{1}{2}$ hours.	24 hours.
Seriatopora hystrix	Lived without apparent injury.	Killed	
Pocillopora bulbosa	Do	Lived	Killed.
Acropora pulchra	Do	Killed	
Goniastrea pectinata	Do	Lived	Killed.
Cœloseris mayeri Vaughan	Do	Do	Half-killed.
Porites murrayensis Vaughan	Do	Do	Lived.
Porites mayeri Vaughan	Do	Half-killed	Half-killed.
Porites andrewsi Vaughan	Do	Killed	

Thus the common reef-flat corals can survive for $4\frac{1}{2}$ hours in 50 per cent sea-water, but only about half of them can survive $11\frac{1}{2}$ hours of this treatment, and only three, *Porites murrayensis*, *Porites mayeri*, and *Cœloseris mayeri*, can withstand 24 hours of this diluted sea-water.[2] In Samoa I found that openings in reefs opposite stream-mouths are places where corals are killed by silt and dilution and thus could never obtain a foothold in such places. The most resistant coral in this respect is the massive *Porites*. In 1915 about 30 inches fell upon Maër Island from November to May and less than 3 inches from May to the end of October.

Samples of the water from definite stations over the reef-flat and from the open sea were taken at various times of the day and states of tide and these were titrated with one-tenth molecular silver-nitrate solution, using potassium chromate as an indicator. These experiments showed that there is no appreciable concentration of the water, even at low tide, over the shoreward parts of the reef-flat due to evaporation, nor was the water at any place diluted by an influx of spring water from the shore, due probably to our visit being near the end of the long dry season which begins in May. The concentration of the waters over the reef-flat was within the limits of error of experiment identical with that of the ocean close to but just outside of the reef, the average of 11 tests giving 36.1 per cent of salinity for both the outer ocean and the reef-flat.

[1]Mr. John Stewart Bruce states in letters that the rainfall on Maër Island from January 1 to April 30, 1914, inclusive, was 30.17 inches, and from May 1 to June 30, 1914, it was 3.51 inches. In 1915 the rainfall was 32.66 inches, of which 24.65 inches fell between January 1 and April 30; the remaining 8 months having only 8.01 inches.

[2]In the summer of 1914, Dr. Vaughan made similar experiments upon 17 species of corals at Tortugas, Florida, and our conclusions are in substantial agreement. See Vaughan's report in Carnegie Inst. Wash. Year Book No. 13, p. 224.

The wide southeast reef-flat of Maër Island is peculiar in that the lithothamnion ridge forms a dam which prevents the water from escaping at low tide thus impounding a huge, shallow lake having a minimum depth of from 4 to 16 inches (see table 1) at low tide, while at high tide the water is everywhere between 7 and 8 feet deep.

One sees that *Seriatopora hystrix*, which is the dominant coral of the middle zone of the reef-flat, is cut off squarely at low-tide level and indeed there are few corals excepting *Acropora* which project more than 2 to 3 inches above the level of the water at low tide.

EXPERIMENTS UPON DRYING CORALS.

Experiments upon drying various corals from this reef confirm Vaughan's conclusions[1] based on his experiments upon the Florida corals, that the forms

Table 12.

Species.	Basal part of stalk immersed in sea-water. Upper part of coral exposed to sun's rays from $10^h\ 15^m$ to $11^h\ 15^m$ a. m. At $10^h\ 15^m$ a. m. Dry bulb 29.2°, wet bulb 24.2°. Humidity 72 p. ct. At $11^h\ 15^m$ a. m. Dry bulb 31.5°, wet bulb 26.1°. Humidity 73.5 p. ct.	Corals placed on a dry bare rock close by side of the other corals. All other conditions the same in both experiments, excepting that in this case the bases of the corals were *not* immersed in sea-water, the entire stalk being dry. Temperature and humidity the same as in preceding column.	Basal part immersed in sea-water, upper parts dried in sun for $1^h 30^m$. Dry bulb 30.35°. Wet bulb 27.4°. Humidity 83.5 p. ct.	Coral wholly dried in the sun $1^h\ 30^m$. Dry bulb 30.35°. Wet bulb 27.4°. Humidity 83.5 p. ct.
Pocillopora bulbosa	Killed	Killed	....	....
Seriatopora hystrix	Killed[2]	Killed	....	....
Acropora pulchra and A. hebes.	Survived without apparent injury.	Killed	....	....
Goniastrea pectinata	Survived without injury	Survived without apparent injury.	....	....
Goniopora tenuidens	Survived without injury	Survived without apparent injury.	....	....
Cœloseris mayeri Vaughan	Survived	Survived	....	....
Porites haddoni Vaughan	The upper parts of the coral were killed. Basal half above the sea-water survived.	Killed	....	....
Montipora ramosa	....	....	Survived without apparent injury.	The coral barely survived, most parts of it being killed.

with spongy skeletons, provided their bases remain immersed, can draw up water by capillary attraction and thus retain their internal moisture even though exposed for an hour or more to the sun's rays at midday. Thus such cavernated forms (as *Acropora* and *Montipora*) and to a more limited degree

[1]Report of T. Wayland Vaughan, Carnegie Inst. Wash. Year Book No. 11, p. 161, 1912.

[2]This species can survive one hour in the sun with the base immersed in sea-water if the maximum temperature is not more than 29.4° and the humidity is about 66.5 per cent, the wet bulb being 24.2° to 25.2° C.

the branching species of *Porites* can long survive being exposed to the air in the hot sun, provided the basal parts of the colony remain immersed in sea-water or in water-soaked mud. This, however, is of little service to the compact corals and thus it is that, even though their basal parts be immersed in salt water, an hour's exposure to the air and sun is sufficient to kill such species as *Seriatopora hystrix* and *Pocillopora bulbosa*.

The results of experiments upon this subject are shown in table 12.

The Great Barrier Reef corals which survive exposure to sun and air at low tides are of the genera *Acropora*, *Montipora*, *Goniastrea*, *Symphyllia*, *Cœloria*, *Mæandra*, *Porites* and other cavernated forms; and this fact will be apparent to any one who inspects the numerous photographs of corals taken by Saville-Kent showing the reefs laid bare at low tide.

THE SOLUBILITY OF LIMESTONE IN SEA-WATER.

The oölitic limestones of Florida and the Bahamas appear to be largely derived from chemically precipitated calcium carbonate which has been thrown down from the sea-water through the agency of bacteria in the manner determined by G. Harold Drew,[1] as amplified by the later studies of Karl F. Kellerman and N. R. Smith, whose researches show that calcium carbonate is precipitated in sea-water when a denitrifying or ammonia-producing bacillus acts in conjunction with a form which produces carbon dioxide. (See Journal Washington Academy of Science, vol. 4, p. 400, August 1914.)

In Torres Straits and the Murray Islands, on the contrary, the bulk of modern reef-forming material consists of corals, shells of mollusca, foraminifera, tests of echinoderms, the calcareous parts of nullipore algæ and remains of other organisms; the material derived from precipitated calcium carbonate is unimportant, and oölitic limestones were not seen by me.

The results of current-scouring and disintegration are seen in the region of Torres Straits, in the many corroded, cavernated, dead coral stocks, and above all in the disappearance of the lithothamnion ridge of fringing reefs in all regions excepting the seaward edge where the breakers dash in full force.

As the fringing reefs grow seaward the older (shoreward) parts of the lithothamnion ridge corrode and disappear and thus the ridge remains merely as a narrow crest along the advancing seaward edge of the reef-flat.

The work of Mr. R. B. Dole[2] at Tortugas upon water samples collected by Vaughan appeared to show that in this Florida lagoon the carbon dioxide in the sea-water is either combined or half combined, none of it being free. Later, Dr. Shiro Tashiro[3] casts doubt upon Dole's opinion that there is no free CO_2 in sea-water, but he did not disprove it, admitting indeed that if

[1]Mr. Drew's latest studies are published in Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, vol. 5, pp. 9–45, Carnegie Inst. Wash. Pub. No. 182, 1914.

[2]Carnegie Inst. Wash. Pub. No. 182, pp. 69–78.

[3]Tashiro, Shiro, 1914, Carnegie Inst. Wash. Year Book No. 13, p. 220; *Ibid.*, No. 14, 1915, p. 217.

free CO_2 be present its concentration must be very slight. However, both Tashiro and Mayer, working independently and pursuing different methods, have shown that calcium carbonate is slightly soluble in Tortugas sea-water[1] which remained alkaline to phenolpthalein. Natural sea-water from Tortugas, Florida, was found by Professor J. F. McClendon to have a hydrogen-ion concentration of from 8.1 to 8.2 PH.

Mayer[2] attempted to determine the rate at which sea-water *as such* can dissolve limestone by placing carefully weighed pieces of *Cassis* shell in sea-water for one year and then reweighing the shells. The experiments showed that if calcium carbonate does dissolve in natural sea-water, the rate of this solution is so slow that it would take at least 1,000,000 years to dissolve off a layer one fathom thick, and thus the lagoons of atolls which are commonly 15 to 20 fathoms deep could not have been dissolved out by sea-water as such even if coral limestone dissolves 100 times as fast as a *Cassis* shell, for most if not all of them are, geologically speaking, of recent formation.

However, admitting that sea-water is a negligible factor in so far as solution of limestone is concerned, this does not necessarily imply that no appreciable solution of dead coral and limestone takes place in lagoons, for the decomposition of plant and animal organisms which lived over the surfaces and within the cavities of coral heads may supply a local source of CO_2 in the exact positions wherein it may be most effective in causing solution of limestone. In fact, living Annelids (Eunicidæ) within the crevices of coral heads are decidedly acid to litmus test, although, as Johnston and Merwin state, this does not necessarily indicate that they dissolve limestone, for, as these authors show, whether sea-water does or does not dissolve $CaCO_3$ depends not only on its temperature and concentration of free CO_2, but also upon the concentration of calcium already present.

One might suppose the outpouring of rain-water from the densely forested volcanic shore during the wet season might introduce carbonic acid into the water of the surrounding reef-flats. However, Mayer tested this upon Tutuila, Samoa, and Oahu, Hawaiian Islands, in 1917, and found that although the rain is acid of the order 10^{-5}, the stream and spring waters of these Islands are *alkaline* having a hydrogen-ion concentration of 10^{-7}. Thus they can not dissolve limestone by reason of their "acidity," and the Murray-Agassiz idea of solution is not supported.

Dead coral broken off and then washed shoreward from the inner edge of the lithothamnion ridge of Maër Island gradually disappears before it reaches the beach, only a few deeply cavernated dead coral heads being found within 350 feet of the shore, where they lie disintegrating in the calm, warm waters of the shallows.

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[1]Carl Elschner (1915, The Leeward Islands and the Hawaiian Group, p. 48) rightly states that the solubility of calcium carbonate in sea-water is extraordinarily low.

[2]Mayer, A. G., Carnegie Inst. Wash. Year Book No. 14, 1915, p. 210; also Proc. National Acad. Sciences, vol. 2, p. 28, 1916.

Scouring by currents and disintegration are, however, of limited efficacy in the deepening of lagoons in the Murray Islands, for the lagoon of the wide southeast reef is only about 18 inches deep at low tide. The effects of scouring and disintegration are, however, constantly counteracted by the thickly-clustered growth of coral heads over the bottom; but on the other hand the corals are being unceasingly disintegrated by wave-action as well as by the activity of echini, holothurians, fish, and other organisms, in the manner described in detail by J. Stanley Gardiner, Wood Jones, Vaughan, Duerden, and others. Thus, independent of solution due to CO_2 provided by the decomposition of plant and animal matter, there are factors which tend to deepen the lagoons, while others tend to fill them up, and the resultant condition represents the balance between antagonistic tendencies, and most if not all lagoons are at present being filled up by an accumulation of limestone, mud, and silt carried into them in the manner described by Guppy,[1] wherein he claims that at least 5,000 tons of sand are annually drawn into the lagoon of Cocos-Keeling through openings between the islets. Wood Jones also decides that this lagoon is filling up, and the same phenomena are reported by Hedley and Taylor for the Great Barrier Reef, and by Vaughan for the Florida-Bahama region and the West Indies, and under certain conditions the varying solubility of different forms of calcium carbonate may lead to the conversion of coral into limestone in the manner explained by Wells,[2] who shows that with fluctuations in temperature particles of calcium carbonate alternately dissolve in and redeposit in the pore space, tending always toward the more stable calcite.

On the flats of the fringing reef surrounding the Murray Islands, however, the balance is set slightly in the other direction and there is evidence of the disappearance of a layer of limestone over the southeast reef, at least 1,200 feet wide and about 2 feet thick; for the amount of loose sand overlying the uniformly hard, rocky, coral-bearing floor of the reef-flat is very slight (see fig. 9) and there is remarkably little limestone sand cast ashore along the entire southeast shore of the island, and as the reef-flat is not disturbed by hurricanes and no strong currents wash over it, in this region at least, some of the lime-stone sand due to disintegration of dead coral, etc., apparently disappears *in situ*, being dissolved in the intestines of the large numbers of holothurians and echini and fish which are constantly swallowing it; also even weak currents of 40 feet per minute are effective in scouring and transporting sand over reef-flats, as I found in Samoa in 1917. The crest of the lithothamnion ridge and those parts of the reef-flat to the seaward of it are not disintegrated, for few echinoderms or other "sand feeders" can gain a foothold upon it, on account of the heavy surge of the breakers in this region. Thus the growth of nullipores and of the other veneering organisms is but little interfered with in the region of the breakers, and this part of the reef-

[1]Guppy, 1889, Scottish Geographical Magazine, vol. 5, p. 472.
[2]Wells, Journal Washington Academy of Science, vol. 5, p. 622, 1915.

flat actually rises about 6 inches above the level of mean low tide. But the limestone of the fringing reef-flat *between* the lithothamnion ridge and the shore has disappeared, leaving a lagoon about 18 inches deep at low tide, and this despite the growth upon it of one of the most densely clustered coral colonies the writer has ever seen. Were it not for the growth of this coral the reef-flat would have suffered even more serious disintegration, and in hurricane regions where the corals on top of the reef-flats are periodically destroyed it seems possible that such a fringing reef as that of Maër Island might gradually become converted into a barrier reef by the solution of the limestone, due to "sand feeders" and to scouring due to currents.

In this fringing reef there seems reason to support the belief that the lithothamnion ridge was once close to the shore, but that it has advanced seaward as the reef-wall grew outward, while at the same time its shoreward side disintegrated, thus forming the present shallow lagoon of the reef-flat which is prevented from becoming deeper only by the densely clustered coral heads which grow upon its floor. In this reef-flat, I believe, we have an example of a fringing reef which, were it not for the luxuriant growth of corals over its floor, would change into a barrier reef. We call it a "fringing reef" because its lagoon is only 1.5 feet deep. If the lagoon were 15 feet deep the reef would be called a "barrier."

Reef corals are, however, not the only organisms which tend to build up limestones, for Cary[1] has shown that at Tortugas, Florida, the *Alcyonaria* are more important than the stony corals, in this respect.

SUMMARY OF CONCLUSIONS.

The factors which chiefly determine the mode of distribution of the various species of corals over the southeast reef-flat of Maër Island, in the order of their importance, are (1) temperature, (2) silt,[2] (3) mechanical effects of moving water, and (4) the struggle for existence between the various species of corals.

For example, *Seriatopora hystrix*, which is the dominant coral of the middle zone of the reef-flat, can not live within 500 feet of the shore on account of its inability to withstand high temperature and muddy water; nor can it live upon the outer 200 feet of the reef-flat, for here the waves shatter its fragile stems; yet in regions between 1,000 and 13,000 feet from shore it succeeds so well that all other species are either crowded out or reduced in numbers, being unable to compete with it for a foothold.

It is remarkable that the ability to resist high temperature is fairly well correlated with a coral's ability to withstand the smothering effects of silt,

[1]Cary, L. R., 1915, Proc. Nat. Acad. Sci., vol. 1, pp. 285–289; also: Carnegie Inst. Wash., Year Book No. 14, pp. 200-201, 1915. Also the last paper of this volume.

[2]There is very little silt upon this part of the reef-flat. In a muddy region silt would certainly be the most important factor in its effect upon coral life.

and this suggests that, physiologically speaking, the effect of high temperature may be to asphyxiate the corals, probably by accelerating their metabolic processes to such a degree that the oxygen of the sea-water is unable to sustain them.

The ability of the various species of corals to resist heat or cold is a physiological matter and the corals of Australia behave essentially as do corresponding genera of Florida. Yet the Australian corals from Murray Island are not called upon to withstand cold, nor do those of Florida commonly have to withstand so high a degree of heat as must the corals of Murray Island. In other words, natural selection has not improved the corals of either region in respect to their ability to resist heat or cold.

In comparison with the effects of heat, of silt, and of wave-action, the influence of dilution of the sea-water due to rains is negligible.

Of the 40 or more species of corals here recorded from the rich southeast reef-flat of Maër Island, only 2 (*Porites andrewsi* Vaughan and *Cœloseris mayeri* Vaughan) are practically confined to within 1,200 feet of the shore; while 14 species are practically restricted to the outer part of the reef-flat and do not approach within 1,200 feet of the shore. Generally speaking, corals thrive best in clear, cool water wherein the range of temperature is but slight; and only a very few, such as *Porites andrewsi* and *Montipora ramosa*, are confined to a habitat wherein the water is subject to wide range in temperature and to being charged at times with silt. *Seriatopora hystrix*, which is very sensitive to high temperature, silt, or dilution, and easily broken by the waves, is confined to the middle zone of the reef-flat.

Large stocks of *Symphyllia* or massive nodular *Porites* may grow so as to enlarge in diameter at the rate of nearly 2 inches (48 mm.) per annum.

The ocean's surface is a good absorber and radiator of heat, and thus the temperature of wide, shallow areas of water over reef-flats is colder than the air at sunrise and warmer than the air at about 3 o'clock in the afternoon.

However they may have been formed, the lagoons of atolls and barrier reefs have not been dissolved out by sea-water as such, the solubility of limestone in sea-water being so slight that this factor is negligible as a cause producing a deepening of lagoons. The effects produced by currents over the reef-flats, and by "sand feeders," such as holothurians and echini, are certainly important as agencies of disintegration, but no quantitative determination of their efficacy has yet been made.

PHOTOGRAPHS OF MAËR ISLAND CORALS.

The distribution of these corals is shown in table 3. They were collected along "Line No. 1" across the southeast reef-flat of Maër Island. The photographs were taken by the author, and are of natural size. The species were determined by Dr. T. Wayland Vaughan, and the specimens are preserved in the National Museum, Washington, D. C.

Plate 12.—Nos. 1 to 3. *Pocillopora bulbosa* Ehrenberg (*fide* Dana). All from the southeast reef-flat of Maër Island, Murray Islands.

No. 1, from about 625 feet from shore in quiet water about 8 inches deep at low tide, on a sandy bottom.

No. 2, from about 1,200 feet from shore in slightly agitated water, about 14 inches deep at low tide, on a rocky bottom.

No. 3, from a shallow tide pool of the lithothamnion ridge, 1,790 feet from shore, washed almost constantly by the breakers.

No. 4. *Seriatopora hystrix* Dana. From the southeast reef-flat of Maër Island about 1,200 feet from shore, in water about 15 inches deep at low tide, on a hard rocky bottom.

No. 5. *Acropora* (*Rhabdocyathus*) *murrayensis* Vaughan. From the southeast reef-flat of Maër Island 1,630 feet from shore, in water about 16 inches deep at low tide, on a hard rocky bottom of broken coral.

Plate 13.—No. 6. *Acropora* (*Lepidocyathus*) *hebes* (Dana). From the southeast reef-flat of Maër Island, Murray Islands. From about 800 feet from shore on a hard rocky bottom, in water about 10 inches deep at low tide.

No. 7. *Acropora* (*Tylopora*) *digitifera* (Dana). From the southeast reef-flat of Maër Island, 800 to 850 feet from shore, in water about 15 inches deep at low tide. Growing on a hard bottom of broken coral.

No. 8. *Acropora* (*Isopora*) *palifera* (Lamarck) var. *a* Brook. From the southeast reef-flat of Maër Island, 1,200 feet from shore, in water 14 inches deep at low tide.

Nos. 9 to 11. *Porites mayeri* Vaughan. From the southeast reef-flat of Maër Island, between 600 to 1,200 feet from shore, in water about 10 to 15 inches deep at low tide.

No. 12. *Porites murrayensis* Vaughan. From the southeast reef-flat of Maër Island, 1,220 feet from shore, in water 16 inches deep at low tide, on a hard rocky bottom.

No. 13. *Porites australiensis* Vaughan. From the southeast reef-flat of Maër Island, 450 feet from shore, in water about 6 inches deep at low tide, on a sandy bottom.

No. 14. *Porites murrayensis* Vaughan. A "rolling stone" specimen from the southeast reef-flat of Maër Island, about 1,000 feet from shore, in water about 15 inches deep at low tide; hard bottom with little sand.

Plate 14.—No. 15. *Porites australiensis* Vaughan. From the southeast reef-flat of Maër Island, 620 feet from shore, on a sandy bottom, in water 10 inches deep at low tide.

No. 16. *Porites andrewsi* Vaughan. From the southeast reef-flat of Maër Island, 600 feet from shore, on a bottom of coral mud and limestone sand, in water about 10 inches deep at low tide.

No. 17. *Gonipora tenuidens* (Quelch). From the southeast reef-flat of Maër Island, 500 to 550 feet from shore, on a sandy bottom, in water about 15 inches deep at low tide.

No. 18. *Cœloseris mayeri* Vaughan. From the southeast reef-flat of Maër Island, between 800 to 1,050 feet from shore, in water between 10 to 15 inches deep at low tide. This is closely related to the form described as *Siderastrea sphæroidalis* Ortmann by J. Stanley Gardiner (1904, Fauna and Geography Maldive and Laccadive Archipelagoes, vol. 2, suppl. 1, p. 936, plate 89, fig. 4).

Plate 14.—*Continued.*

No. 19. *Mæandra astreiformis* Milne Edwards and Haime. From the southeast reef-flat of Maër Island, about 1,650 feet from shore, on a hard rocky bottom, in water 15 inches deep at low tide.

No. 20. *Mæandra dædalea* Ellis and Solander. From the southeast reef-flat of Maër Island, 1,632 feet from shore, on a hard rocky bottom, in water 14 inches deep at low tide.

Plate 15.—No. 21. *Goniastrea pectinata* (Ehr.) From the southeast reef-flat of Maër Island, about 700 feet from shore, in water about 12 inches deep, on a sandy bottom.

Nos. 22 and 23. *Goniastrea pectinata* (Ehr.) From the southeast reef-flat of Maër Island, between 525 to 650 feet from shore, on a sandy bottom, in water 8 to 10 inches deep at low tide.

No. 24. *Goniastrea retiformis* (Lamarck). From the southeast reef-flat of Maër Island, about 1,225 feet from shore, on a hard rocky bottom, in water about 16 inches deep at low tide.

Plate 16.—No. 25. *Goniastrea retiformis* (Lamarck). From the southeast reef-flat of Maër Island, 500 to 550 feet from shore, on a sandy and limestone mud bottom, in water about 6 inches deep at low tide.

No. 26. *Favia pallida* (Dana) facies 3 of Vaughan. From the southeast reef-flat of Maër Island, 1,660 feet from shore, on a hard rocky bottom, in water 14 inches deep at low tide.

No. 27. *Favia pallida* (Dana) facies 6 of Vaughan. From the southeast reef-flat of Maër Island, 1,020 feet from shore, on a rocky bottom, in calm water 12 inches deep at low tide.

No. 28. *Favites virens* (Dana). From the southeast reef-flat of Maër Island, 1,635 feet from shore, on a hard rocky bottom, in water 16 inches deep at low tide.

No. 29. *Favia pallida* (Dana) facies 4 of Vaughan. From the southeast reef-flat of Maër Island, 1,630 feet from shore, on a hard rocky bottom, in water about 16 inches deep at low tide.

No. 30. *Favia pallida* (Dana) facies 6 of Vaughan. From the southeast reef-flat of Maër Island, 1,645 feet from shore, on a hard rocky bottom, in water 13 inches deep at low tide.

No. 31. *Favites abdita* (Ellis and Solander). From the southeast reef-flat of Maër Island, 1,630 feet from shore, on a hard rocky bottom, in water about 15 inches deep at low tide.

Plate 17.—No. 32. *Orbicella curta* Dana. From the southeast reef-flat of Maër Island, in a tide-pool of the lithothamnion ridge, 1,755 feet from shore, in water 3 inches deep at low tide; exposed to the wash of the breakers.

No. 33. *Leptastrea purpurea* (Dana) var. From the southeast reef-flat of Maër Island, about 1,650 feet from shore, on a hard rocky bottom, in water about 16 inches deep at low tide.

No. 34. *Leptoria gracilis* (Dana). From the southeast reef-flat of Maër Island, 1,640 feet from shore, on a broken coral bottom, in water about 14 inches deep at low tide.

No. 35. *Symphyllia nobilis* (Dana). From the southeast reef-flat of Maër Island, 1,625 feet from shore, on a hard rocky bottom, in water about 14 inches deep at low tide.

No. 36. *Astreopora ocellata* Bernard. From the southeast reef-flat of Maër Island, about 1,650 feet from shore, on a hard rocky bottom, in water 14 to 16 inches deep at low tide.

No. 37. *Astreopora ocellata* Bernard. From the southeast reef-flat of Maër Island, about 1,225 feet from shore, in water 16 inches deep at low tide, on a hard bottom of broken coral.

No. 38. *Cyphastrea serailia* (Forskål). From the southeast reef-flat of Maër Island, 1,020 feet from shore, on a rocky bottom, in water about 14 inches deep at low tide; photograph 1.4 natural size.

Plate 18.—No. 39. *Cyphastrea serailia* (Forskål). Immature. From the southeast reef-flat of Maër Island, 1,650 feet from shore, in water about 16 inches deep at low tide, on a hard rocky bottom.

No. 40. *Stylophora pistillata* (Esper). From a shallow cleft-pool in the lithothamnion ridge of the southeast reef of Maër Island, on a hard rocky bottom, 1,740 feet from shore, in water 2.5 inches deep at low tide; exposed to the full force of the breakers.

No. 41. *Acrhelia horrescens* (Dana). From the southeast reef-flat of Maër Island, about 1,025 feet from shore, in water about 14 inches deep at low tide, on a hard rocky bottom.

No. 42. *Hydnophora microconos* (Lamarck). From the southeast reef-flat of Maër Island, 1,640 feet from shore, on a hard rocky bottom, in water 14 inches deep at low tide. October 1913.

No. 43. *Psammocora gonagra* Klunzinger. From the southeast reef-flat of Maër Island, 545 feet from shore, on a rocky bottom, in water 11 inches deep at low tide.

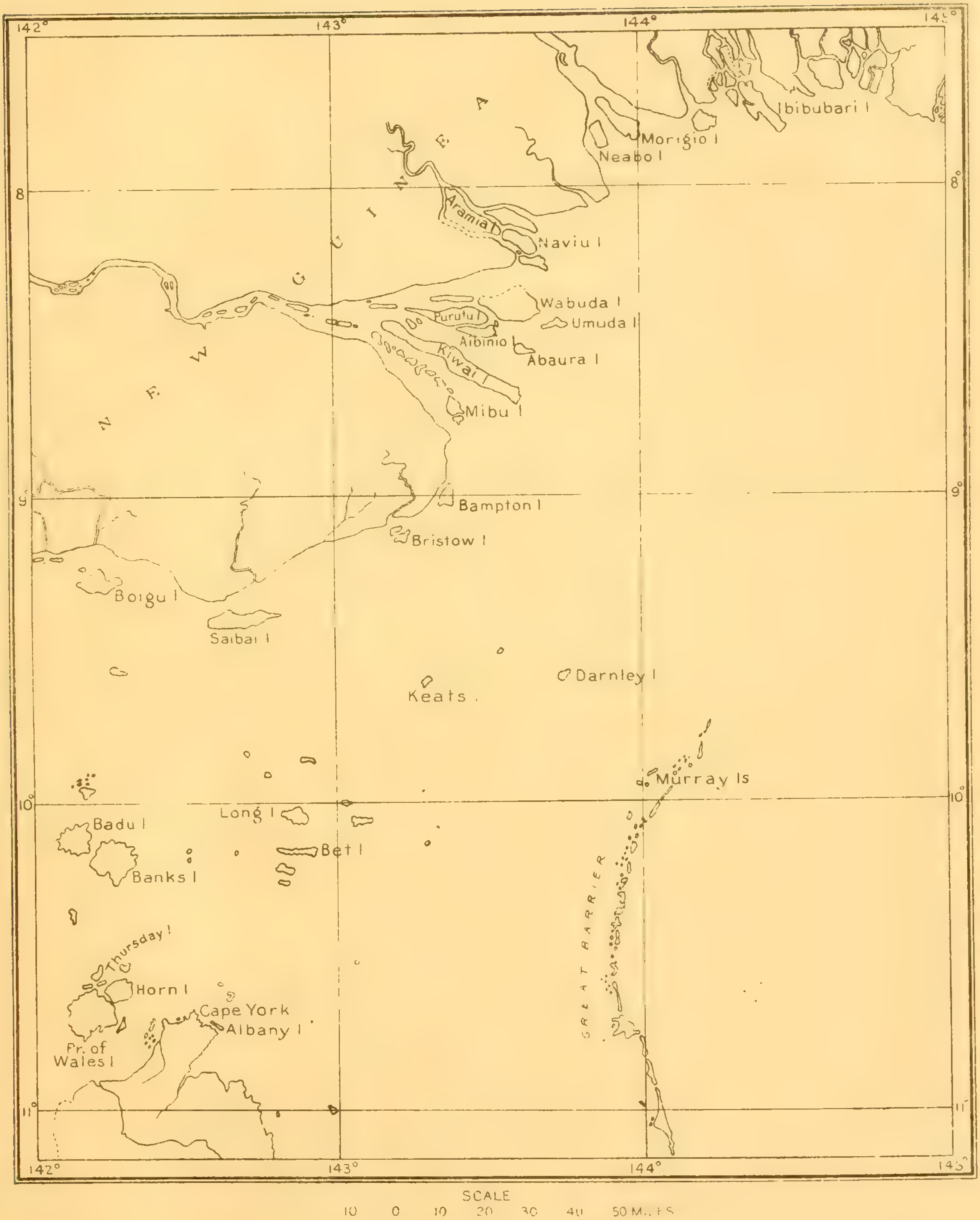
No. 44. *Pavona varians* Verrill. From the southeast reef-flat of Maër Island, 830 feet from shore, on a hard bottom of broken coral, in water 14 inches deep at low tide.

Plate 19.—No. 45. *Montipora ramosa* Bernard. From the northwest side of Maër Island, 180 feet from shore, on a grass-flat laid bare at the spring tides; firm, sandy bottom.

No. 46. *Montipora venosa* (Ehrenberg). From the southeast reef-flat of Maër Island, 1,640 feet from shore, on a hard rocky bottom, 15 inches deep at low tide.

No. 47. *Montipora sp. aff. informis* Bernard. From the southeast reef-flat of Maër Island, about 1,425 feet from shore, on a hard bottom of broken coral, in water 14 inches deep at low tide.

No. 48. *Euphyllia glabrescens* (Chamisso and Eysenhardt). From the southeast reef-flat of Maër Island, 820 feet from shore, in protected crevices, on a bottom of broken coral, in water 10 inches deep at low tide.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NEW GUINEA
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Morigio I
Neabo I
Aramia
Naviu I
Wabuda I
Purutu I
Umuda I
Aibinio
Abaura I
Kiwai I
Mibu I
Bampton I
Bristow I
Boigu I
Saibai I
Darnley I
Keats
Murray Is
Long I
Badu I
Bet I
Banks I
GREAT BARRIER
Thursday I
Horn I
Cape York
Albany I
Pr. of Wales I
SCALE
10 0 10 20 30 40 50 MILES

MAER ISLAND

S Lat. 9° 55′ E. Long. 144° 2′

From Surveys by Captain Owen 1891 and A G Mayer 1913

A

B

A. Inner wall of the western rim of the ash-crater in Maër Island near the highest point of the ridge.

B. View from the summit of the ash-crater of Maër Island, showing old lava-flow at the northeast end of the island which is now covered with palm trees.

A

B

A. Palm-covered sand beach near the middle of the northwest side of Maër Island.

B. Under-cut ash precipice and old elevated shore-line near the southern corner of Maër Island.

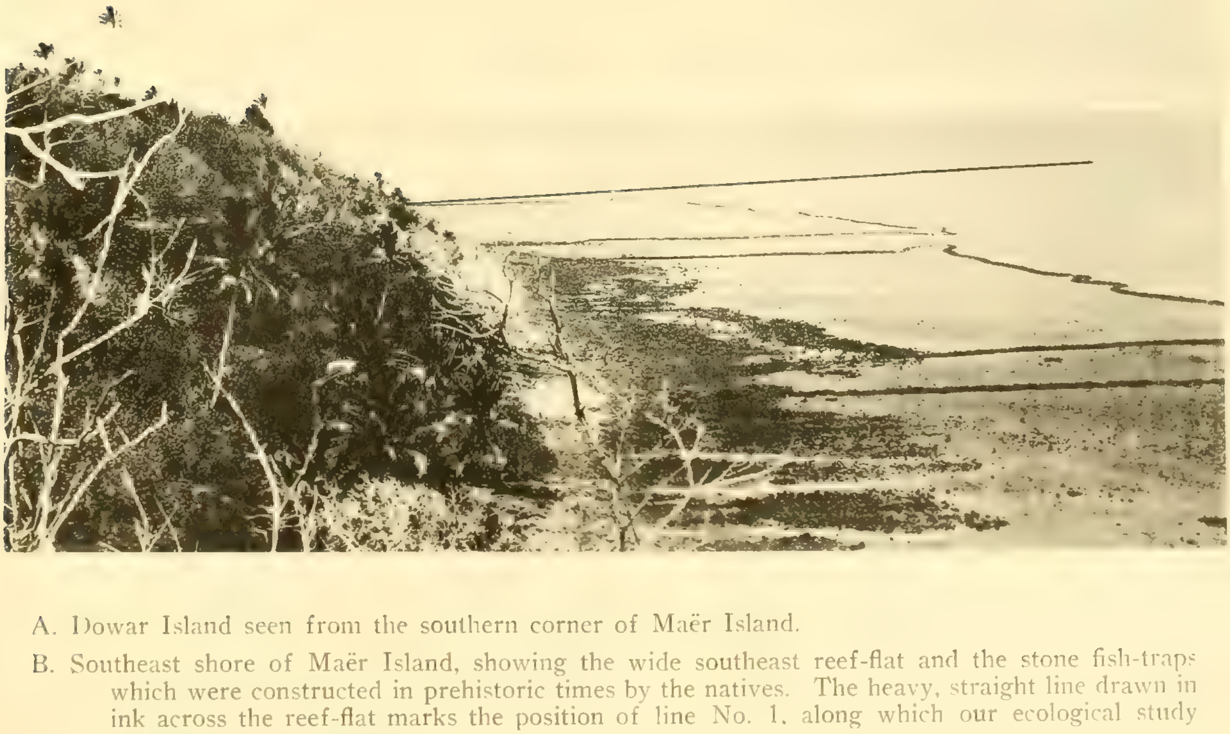

A


B

A. Near the middle of the elevated southeast beach of Maër Island. The wave-worn boulders of lava are now protected from further marine erosion by the coral reef which has grown seaward from the old shore line.

B. Near the western corner of Maër Island looking southward, showing the sand beach covered with palms. Dowar Island in the distance.

A



B

A. Dowar Island seen from the southern corner of Maër Island.

B. Southeast shore of Maër Island, showing the wide southeast reef-flat and the stone fish-traps which were constructed in prehistoric times by the natives. The heavy, straight line drawn in ink across the reef-flat marks the position of line No. 1, along which our ecological study of the corals was made.

A

B

A. Wyer Island and its surrounding reef, seen from the summit of Dowar Island. (Photograph taken by E. M. Grosse.)

B. The sea-invaded crater of Wyer Island, looking southward from the middle of the northern rim of the crater.

A

B

A. Wyer Island. The northern wall of the crater, showing results of erosion.

B. View from the summit of the shore cliff near Faaa, Tahiti, showing the shore plain of Tahiti and also the shore cliff and coastal plain of the neighboring island of Eineo.

A

B

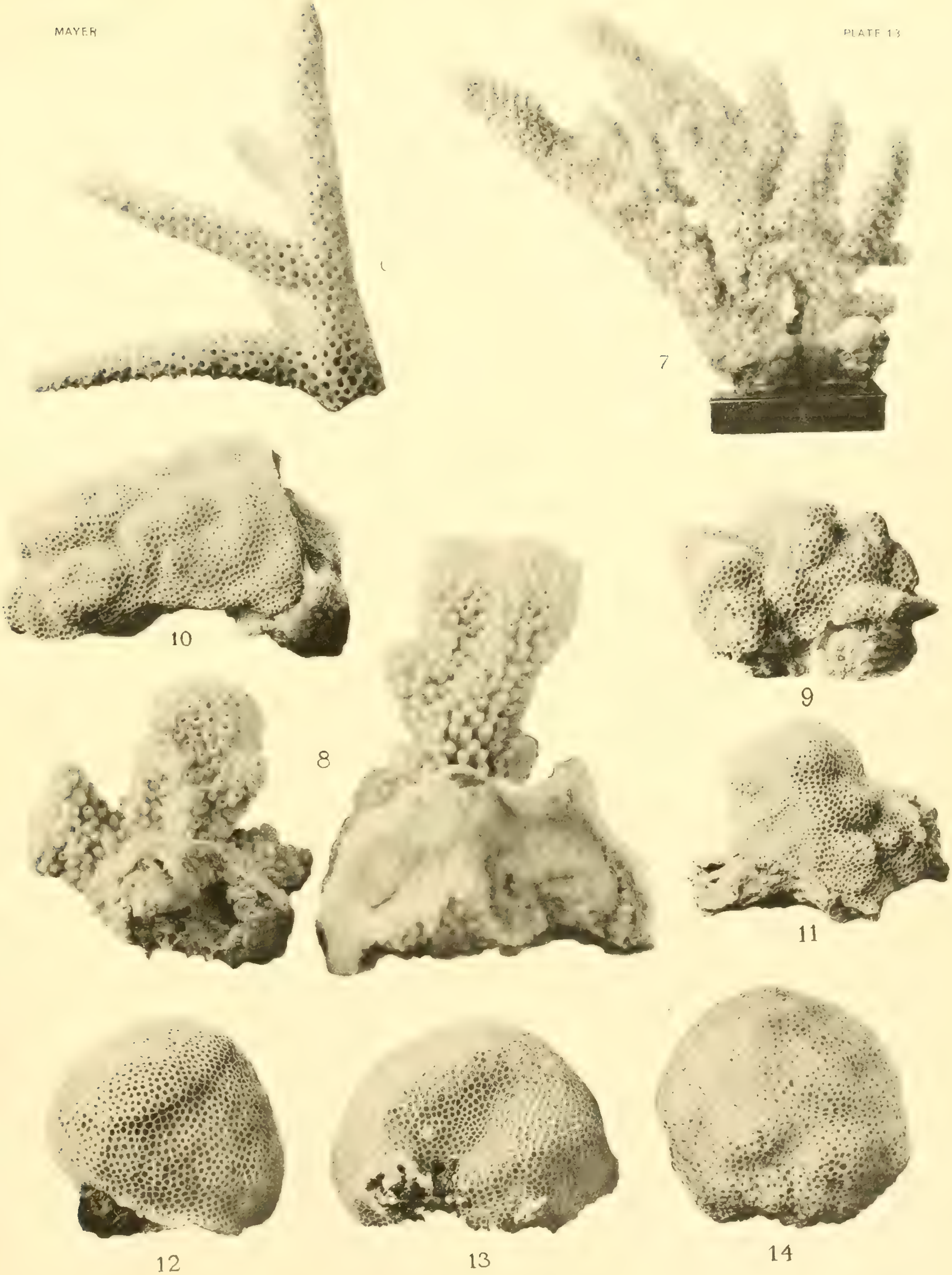
A. The "lithothamnion ridge" along the outer edge of the southeast reef of Maër Island. The ridge is shown laid bare at the low spring tide of September 30, 1913.

B. Two stocks of *Seriatopora histrix*, which were removed from their habitat at about 1,000 feet from shore and taken into shallow water near the beach in order to be photographed. The top of the larger stock is cut off squarely at the level of lowest tides

Reproduction of Plate II. from Saville Kent's "Great Barrier Reef of Australia," showing the corals he measured in 1890 off Vivien Point, Thursday Island.

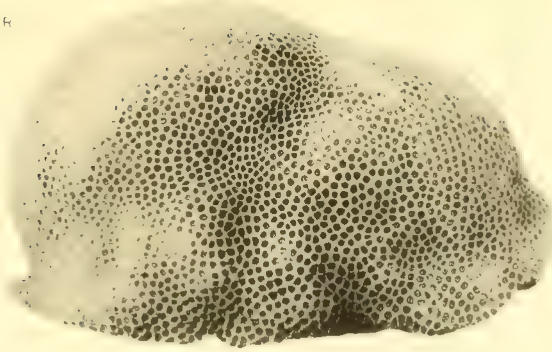
Saville-Kent's Symphyllia as it was on Nov. 8, 1913. The tide is rising, the time being sunrise.

1, 2, 3. Pocillopora bulbosa Ehr. 4. Seriatopora hystrix Dana.
5. Acropora murrayensis Vaughan.



6. Acropora hebes (Dana).
7. Acropora digitifera (Dana).
8. Acropora palifera (Lam.) var. *a* (Brooks)

9, 10, 11. Porites mayeri Vaughan.
12, 14. Porites murrayensis Vaughan.
13. Porites australiensis Vaughan



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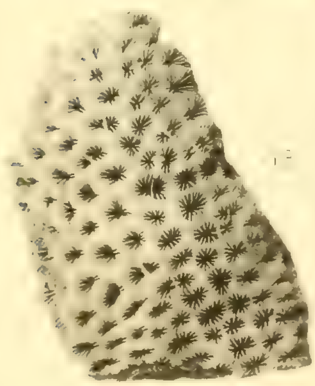
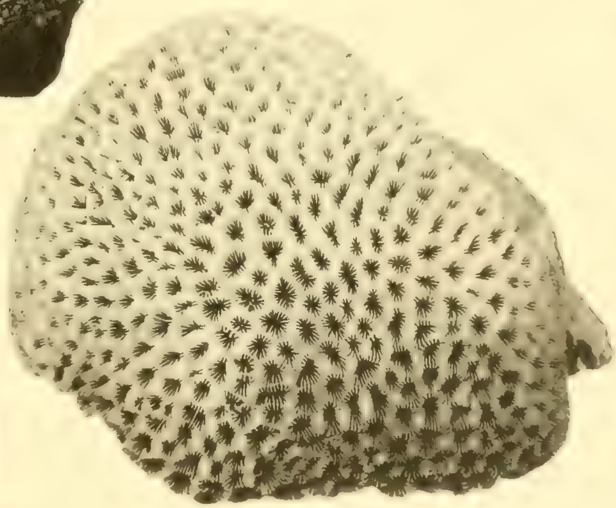
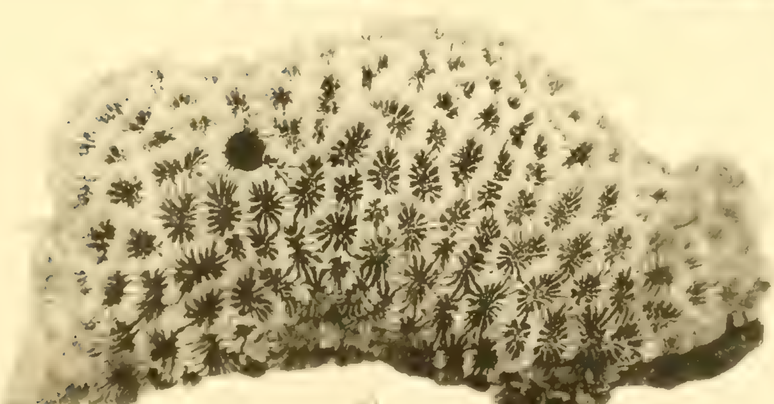
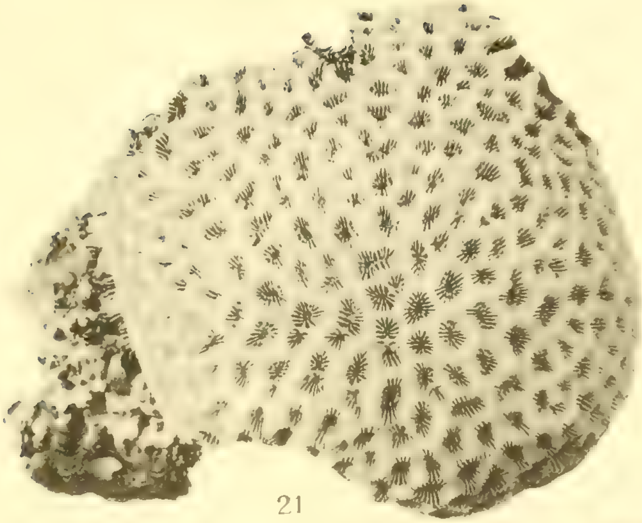






15. Porites australiensis Vaughan.
16. Porites andrewsi Vaughan.
17. Goniopora tenuidens (Quelch).
18. Cœloseris mayeri Vaughan.
19. Mæandra astreiformis (M. Edw. & H.).
20. Mæandra dædalea (Ell. and Sol.).



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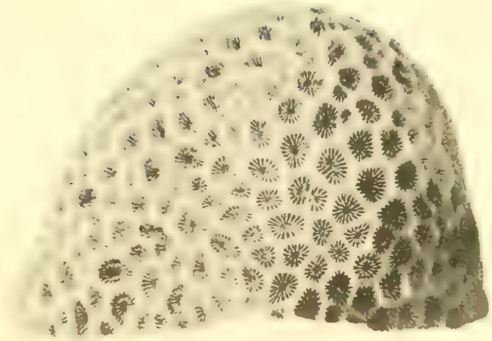

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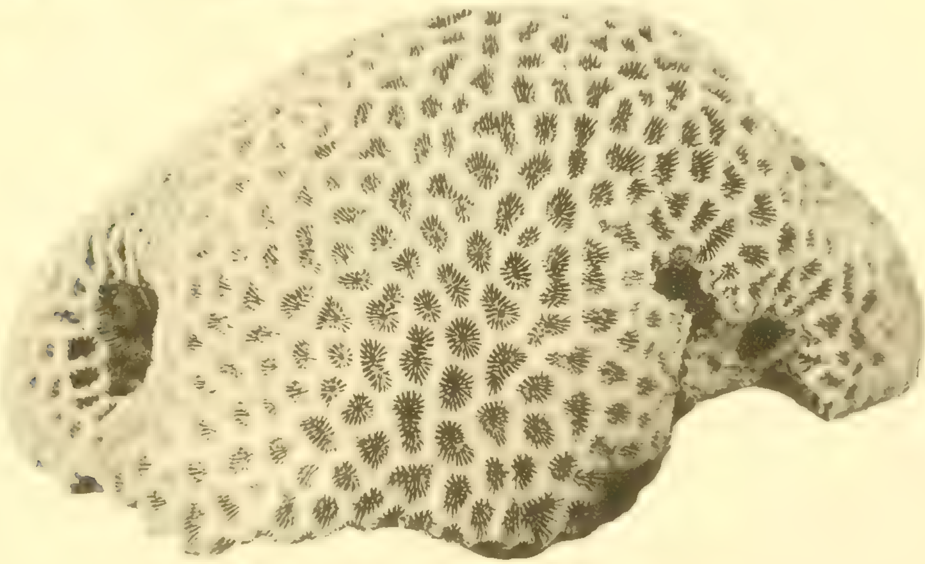

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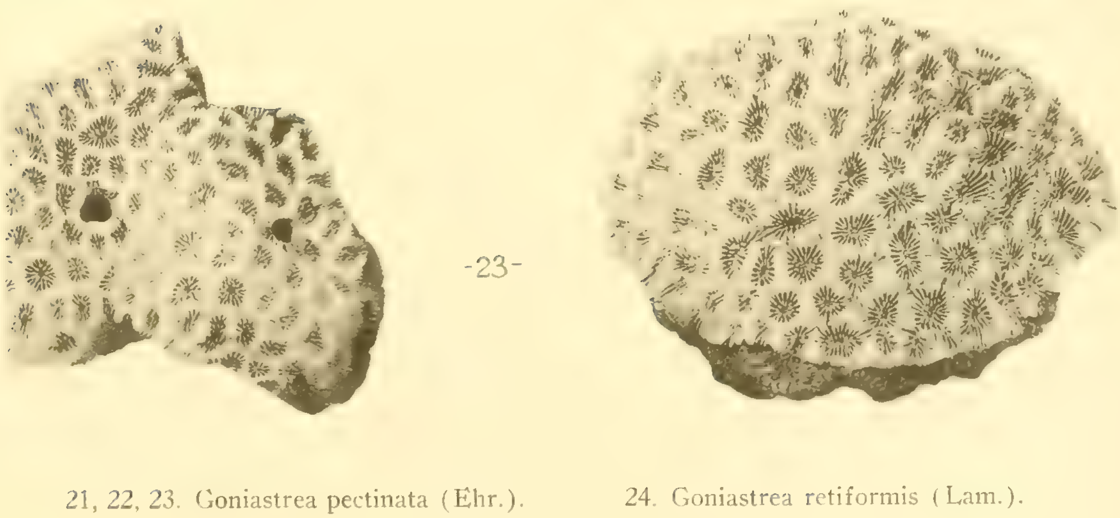
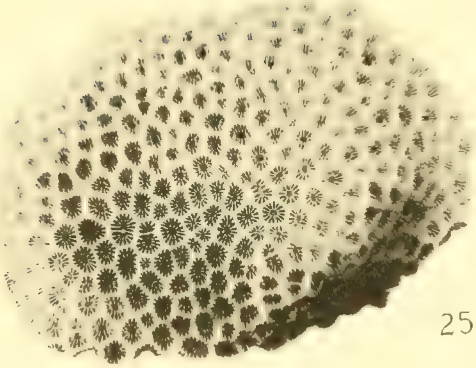


-23-

21, 22, 23. Goniastrea pectinata (Ehr.). 24. Goniastrea retiformis (Lam.).



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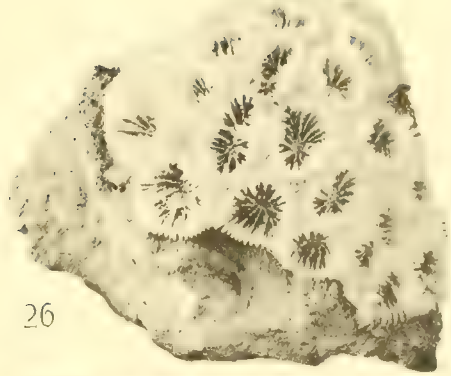

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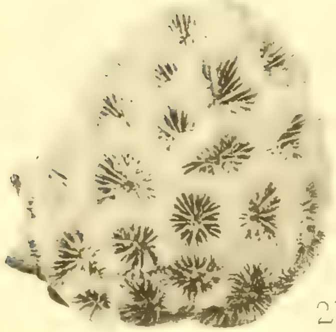

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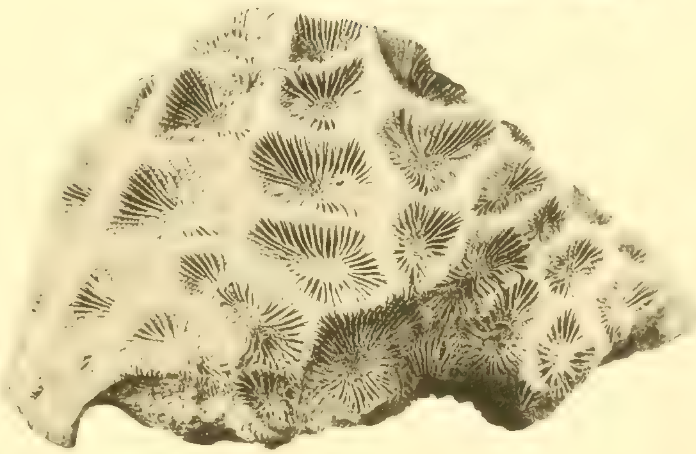

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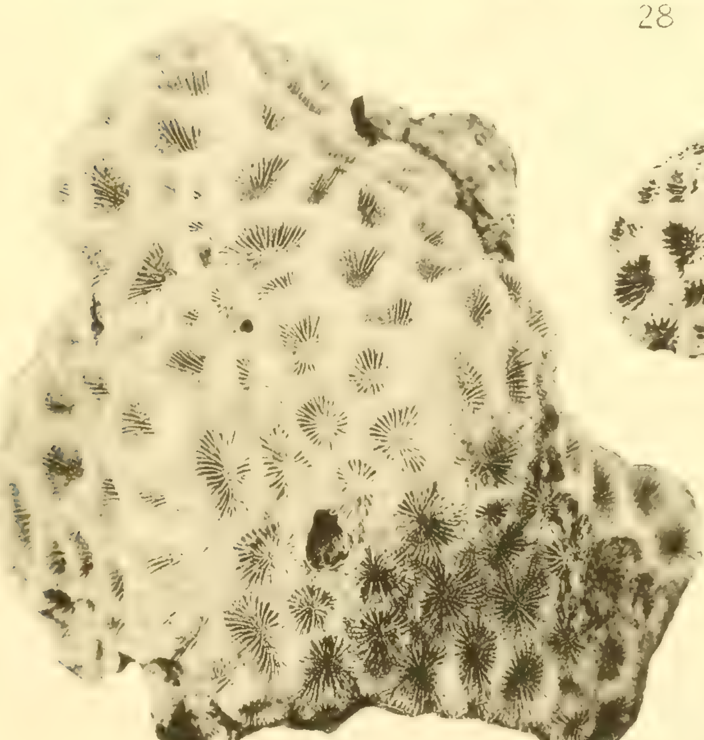

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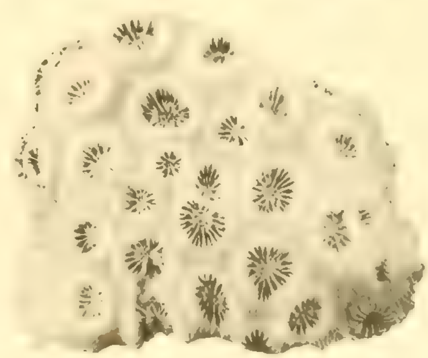

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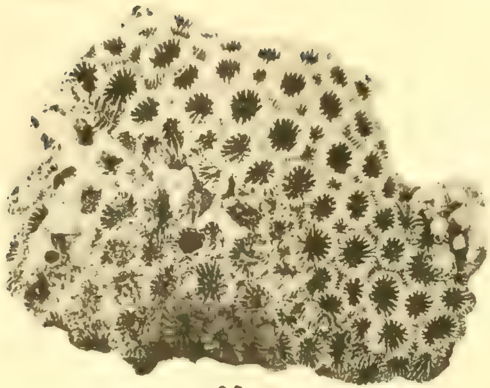
25. Goniastrea retiformis (Lam.).
26. Favia pallida (Dana), facies 3 of Vaughan.
27. Favia pallida (Dana), facies 6 of Vaughan.
28. Favites virens (Dana).
29. Favia pallida (Dana), facies 4 of Vaughan.
30. Favia pallida (Dana), facies 6 of Vaughan.
31. Favites abdita (Ell. & Sol.).



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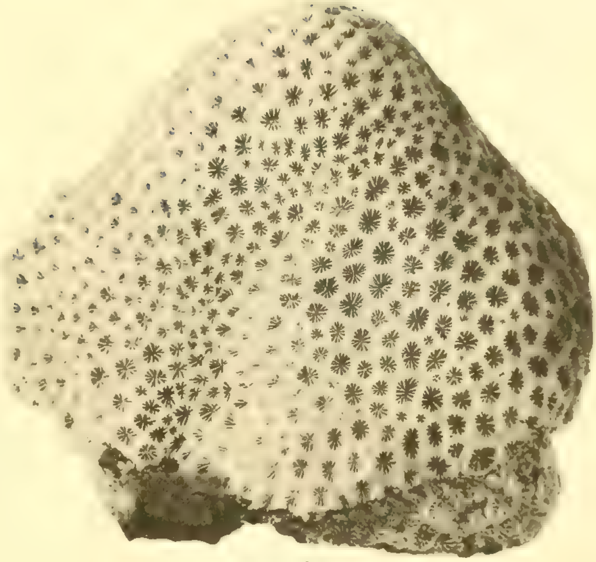

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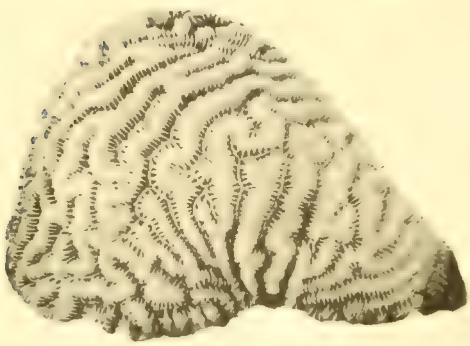

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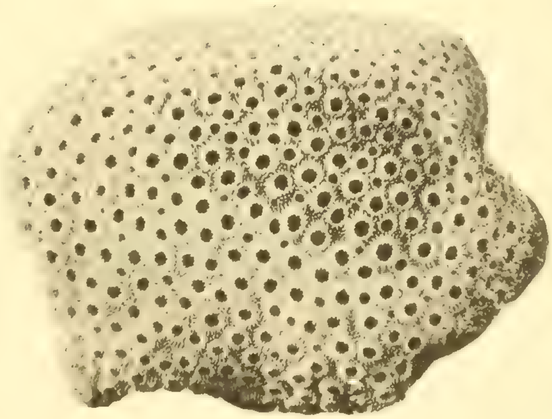

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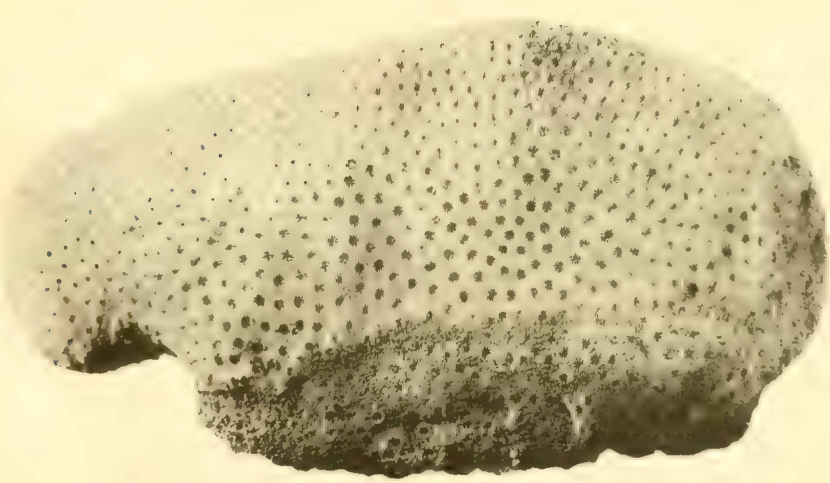

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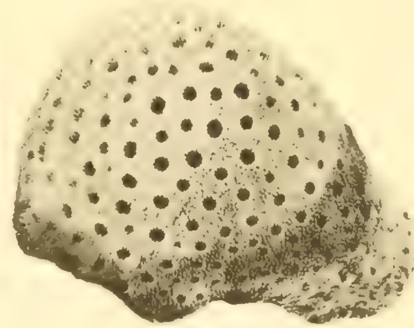

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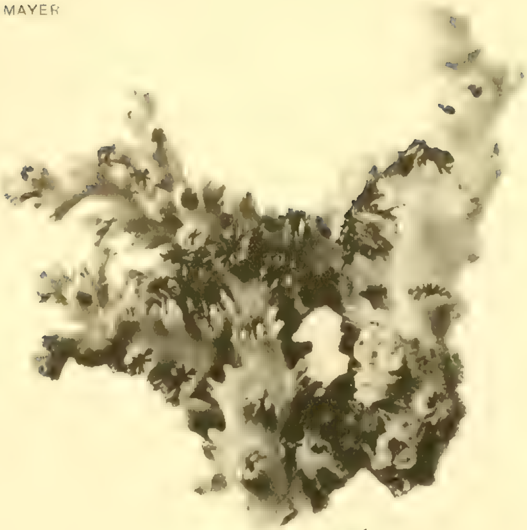
32. Orbicella curta (Dana).
33. Leptastrea purpurea (Dana).
34. Leptoria gracilis (Dana).
35. Symphyllia nobilis (Dana).
36, 37. Astreopora ocellata Bernard.
38. Cyphastrea serailia (Forskal).



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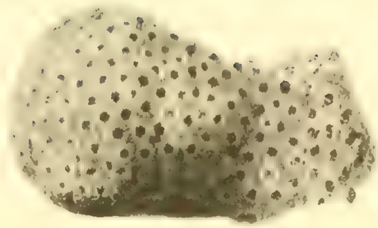

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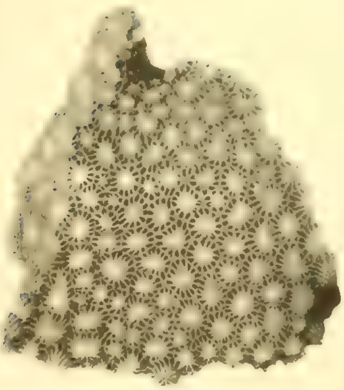

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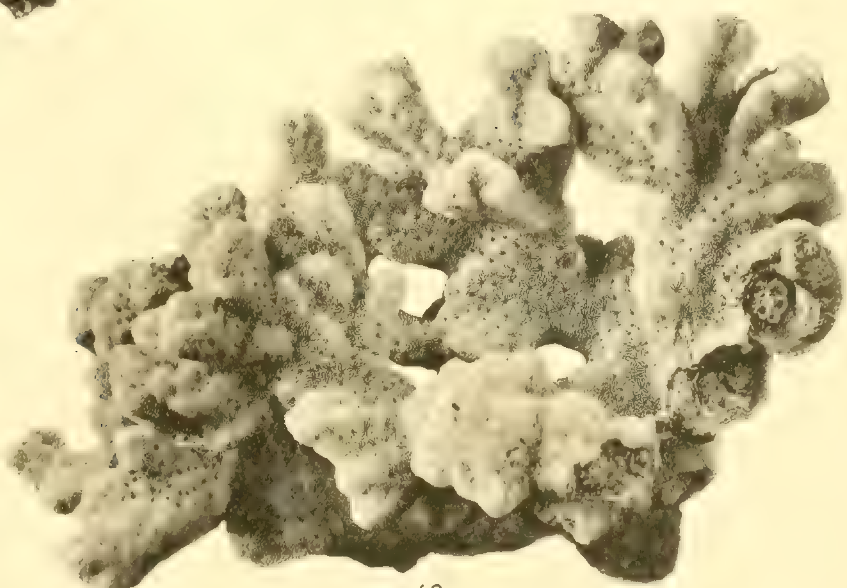

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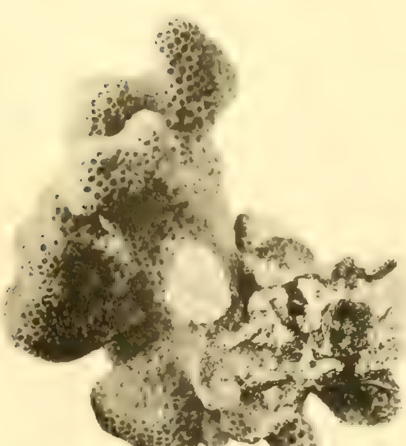

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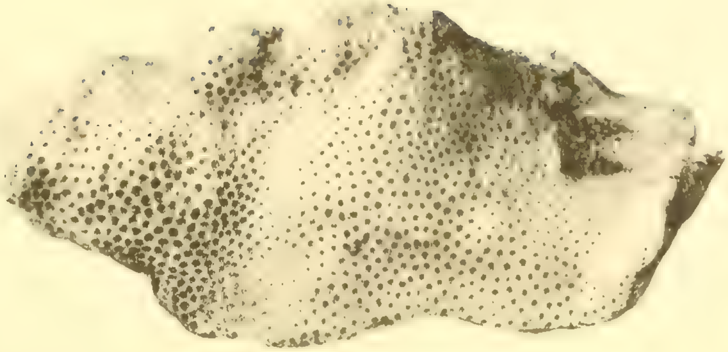
39. Cyphastrea serailia (Forskal).
40. Stylophora pistillata (Esper).
41. Acrhelia horrescens (Dana).
42. Hydnophora microconos (Lam.).
43. Psammocora gonagra Klunzinger.
44. Pavona varians Verrill.



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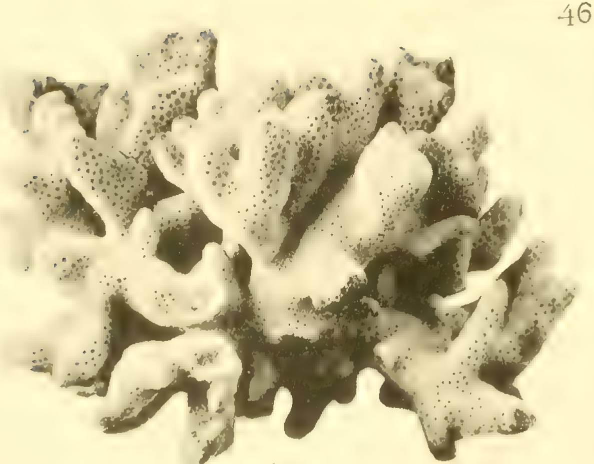

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45. Montipora ramosa Bernard.
46. Montipora venosa (Ehr.).
47. Montipora aff. informis Bernard.
48. Euphyllia glabrescens (Cham. and Eysenh.).

SOME SHOAL-WATER CORALS FROM MURRAY ISLAND (AUSTRALIA), COCOS-KEELING ISLANDS, AND FANNING ISLAND

By Thomas Wayland Vaughan

Geologist in Charge of Coastal Plain Investigations, U. S. Geological Survey, and Custodian of Madreporarian Corals, U. S. National Museum

Seventy-four plates and two text-figures

CONTENTS.

SOME SHOAL-WATER CORALS FROM MURRAY ISLAND (AUSTRALIA), COCOS-KEELING ISLANDS, AND FANNING ISLAND.

INTRODUCTION.

The following statement is intended to show the relations which the present memoir bears to other researches on which I have been and still am engaged, and to serve as an introduction both to this paper and to others which are expected to follow in rather rapid succession, as the manuscripts for several volumes are now almost ready for press.

The studies, which I began in 1892 on the Tertiary corals of the United States and the Caribbean area, had several objects, including: (1) the description of the successive coral faunas for the aid they might render in geologic correlation; (2) the tracing of the relations between the successive faunas in the hope that information might be obtained on their evolution; (3) consideration of the ecology of the faunas for the light which might be thrown on the conditions, especially those of depth and temperature, under which the sediments in which they are embedded were deposited. It soon became evident that to understand properly the fossil faunas of the areas mentioned it was necessary to study those now living in the western Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea. Most of the papers listed on pages 60–61, which were published between 1894 and 1905, resulted from my efforts to accumulate and record information on these subjects.

As the investigations progressed, it became more and more obvious that, to give my geologic deductions a firmer foundation, I should further extend my systematic knowledge of living coral faunas and should study more critically the relations of the faunas to environmental factors. I therefore welcomed the opportunities offered by Mr. Alexander Agassiz to report on collections made in the Pacific by the *Albatross*, while under his direction, and by Professor C. H. Gilbert to report on the Madreporaria from the Hawaiian Islands and Laysan. These collections were supplemented by that portion of a collection made in 1904 by Dr. Charles Gravier in French Somaliland, which could be safely transported to the United States. The papers which resulted from the study of these Pacific collections and the associated problems were published between 1905 and 1910. Their titles are given in the bibliography, page 61.

In 1907 Dr. Alfred G. Mayer invited me to undertake investigations of the corals along the Florida coral-reef tract in connection with the Marine Biological Laboratory of the Carnegie Institution of Washington. This invitation was submitted to the chief geologist of the U. S. Geological Survey, and was accepted on a cooperative basis, which was that facilities for field work should be furnished by the Marine Biological Laboratory, and that

office facilities in Washington, for the study of collections and the preparation of reports, should be furnished by the U. S. Geological Survey. The field work has been completed as originally planned, but all the contemplated reports have not yet been submitted for publication.

As I had been continuously engaged on studies of the geology and geologic history of the Coastal Plain of the United States since about 1889, as the motive for my investigations on corals was to obtain information for use in interpreting geologic history, and as I was in charge of the geologic investigations of the Coastal Plain for the U. S. Geological Survey at the time I began work in association with the Marine Biological Laboratory, it is natural that the opportunity to study the great variety of geologic processes and other geologic phenomena, so well exemplified in southern Florida and the Bahamas, would not be neglected. Furthermore, as I had been engaged in studying the stratigraphy, paleontology, and geologic history of the perimeters of the Gulf of Mexico and the Caribbean Sea ever since I began geologic work, provisions for an extension of my experiences in the region came from a number of sources. In 1901 I was one of three geologists detailed by the Director of the U. S. Geological Survey to the Military Governor of Cuba for the purpose of making a geologic reconnaissance of that island; minor grants from the Carnegie Institution of Washington made possible investigations in the Lesser Antilles; and the Isthmian Canal Commission and the U. S. Geological Survey supported field work in the Canal Zone. Having received assistance from so many organizations in a complex of interlocking problems, it is well-nigh impossible to be specific in acknowledging the credit due each.

The investigations have been according to a plan which will here be briefly outlined, first considering those on the variation and ecology of corals, the outline for which was given in my paper on the Madreporaria of the Hawaiian Islands and Laysan, as follows:

"Variation in the Madreporaria[1] should be studied in three ways: (1) In nature without experiment; (2) in nature by experiment; (3) under artificial conditions in aquaria.

"1. *In nature without experiment.*—Coral fields, according to this method, should be ecologically surveyed. The study of specimens of the same species obtained under the same physical conditions would give information on gametic variation, while the comparative study of specimens belonging to the same species, obtained under different physical conditions, would throw light on the influence exerted by the environment. Numerous fragmentary studies of this kind have been made, but none has been thoroughly done. As much information obtained in this way, as is possible, is given in the present memoir.

"2. *In nature by experiment.*—By planting attached young under the same physical conditions gametic variation could be observed. By transplanting specimens from one area to another, or by planting the young of a given colony under different physical conditions, the effect of environment could be studied.

[1]U. S. Nat. Mus. Bull. 59, pp. 6–7, 1907.

"3. *Under artificial conditions.*—As corals can be grown in aquaria, numerous experiments on both gametic and vegetative variation are possible. The behavior with reference to at least seven factors can be studied: Food supply, heat, light, character of bottom, strength of current, degree of salinity of the water, various kinds of impurities in the water. Even the influence of pressure might be studied.

"The study of variation in nature should go more or less in hand with the experimental work. It is to be hoped that studies of the kind here outlined will be undertaken by some of our marine biological stations, and that other stations that can undertake such work will be established, for until these studies are made it will not be possible to understand variation in the Madreporaria. Until variation is understood the systematic work must be more or less unreliable; and until more is known concerning the physiology of corals we can not understand the factors that determine their distribution."

In my Hawaiian paper I devoted special attention to the relations of corals to depth, temperature, and character of bottom, and under the caption "Additional factors governing the distribution of Madreporaria," it is said:

"Dana says:[1] 'The range of temperature 85° to 74° gives sufficient heat for the development of the greater part of coral-reef species; and yet the temperature at the 100-foot plane in the middle Pacific is mostly above 74°. The chief cause of limitation in depth is the diminished light, as pointed out by Professor T. Fuchs.'

"Pressure and diminished light are both correlative with depth. Both factors need further investigation. Another factor that needs study is the food supply, and probably the oxygen content of the water. Some of the factors to which considerable attention has been paid are not considered here, such as position with reference to the lines of the breakers, relations to the fall and rise of the tides, etc.

"As yet comparatively few facts bearing upon the fundamental principles which determine the distribution of corals have been collected. Most authors have contented themselves with merely mentioning the station and depth at which a given form was procured; they usually have not utilized even these data in attempts to discover any underlying principles. We need much more information and more tabulations of the physical surroundings under which the forms, from individuals to genera, have lived; and a wide range of phenomena should be made the subject of experimental physiological investigation.

"The understanding of the relations of organisms to their physical environment is of the utmost importance to the paleontologist, for it is by the application of such knowledge that he is able to reconstruct the conditions under which organisms now extinct once lived."

In the work on the corals in Florida and the Bahamas, their relations to the following factors have been specially studied: Depth; currents, winds, breakers; character of bottom; sediment; mechanisms for catching food; nature of the food; light; temperature; salinity; atmospheric exposure; conditions favorable and unfavorable for the settling of planulæ; duration of the free-swimming larval stage; organic associations unfavorable to their life; normal organic associations; growth-rate. The results of all these investigations have been published in progress reports in Year Books Nos. 7 to 14 of the Institution, and in other short papers, but they have not appeared, except in abstract, under a single cover. References to the series of articles

[1] U. S. Nat. Mus. Bull. 59, pp. 46–47, 1907.

may be found on pages 61 and 62. The manuscript of a paper bringing together all the results is almost finished, and should soon be ready for press.

Regarding the investigations of coral reefs, of which the study of the ecology of corals is only a part, I will say that in my opinion they should be investigated from at least the following different standpoints:

(1) The corals themselves, to ascertain the ecologic conditions under which they live or lived, and to distinguish the calcium carbonate secreted by corals from that contributed through other agencies.

(2) A complex of geologic processes operating in the area must be studied, analyzed, and evaluated. Among these are the agencies other than corals whereby calcium carbonate may be taken from the sea-water, the probability of the solvent action of sea-water on calcium carbonate, the effects of winds, currents, and waves in building, shaping, and destroying banks, and in submarine planation.

(3) The stratigraphic and structural geology of the area, including a careful study of the origin of the sedimentary rocks with which corals are associated.

(4) The physiography, especially that of the shore-line, that of the land area adjacent to the shore, and that of the sea-bottom from the shore to abyssal depths.

By following the suggested program the ecologic factors influencing reef development, the constructional rôle of corals and other agents, the factors which determine the form of the reef, and the series of geologic events which preceded any particular reef development may be ascertained; but should any part of the program be omitted the results will *not be conclusive.*

My work on Indo-Pacific corals between 1902 and 1907 made me keenly conscious of the meagerness of knowledge of the faunas of certain areas. For the Red Sea, the east coast of Africa, and the Maldives and Laccadives, we have the work of several students, including Klunzinger and von Marenzeller for the Red Sea, Gravier and myself for French Somaliland, and Gardiner for the Maldives and Laccadives; but there were only scattered notes on the Cocos-Keeling Islands. In the Pacific, Dana, Quelch, and Gardiner have made the Fijian fauna fairly well known, Bedot has monographed the corals of Amboina, and I have published a monograph on the Hawaiian fauna; but the coral faunas of two great coral areas, Australia and the Philippines, have been inadequately described, although there is a considerable literature on each. Therefore, when Dr. Mayer offered to make a collection of corals at Murray Island, I expressed the hope that I might find time to write a report on it; but I had not expected to undertake the preparation of the report immediately upon receipt of the material. However, upon his return to the United States Dr. Mayer requested me to identify the set of numbered specimens specially illustrating the corals on which he had made observations and experiments at Murray Island. Compliance with his desire necessitated not only critically working over the entire collection made by him, but also reviewing the species of each genus represented. Before passing to the other collections described in this paper, it will be said that most of the specimens submitted by Dr. Mayer were obtained at intervals of 200 feet, beginning at 400 feet from shore on what he designates as line I, southeast reef, and

extending to 1,600 feet from shore, and from the Lithothamnion ridge, 1,725 to 1,775 feet from shore. The specimens were packed in separate lots, according to station, all those from one station being put together and a label indicating the station, depth of water at low tide, and character of bottom was included in the package with them. Besides these, there were specimens from other localities, all properly labeled. The total number of specimens is about 300. In addition to Dr. Mayer's collection, there are in the U. S. National Museum a few specimens from Torres Strait, purchased from dealers.

As a result of correspondence referred to me by Dr. Mayer, Dr. F. Wood Jones transmitted to me, and subsequently donated to the U. S. National Museum, his collection of about 100 specimens from the Cocos-Keeling Islands, which he used to illustrate his article entitled, "On the growth-form and supposed species in corals,"[1] and his book "Coral and Atolls."[2] He also sent his note-book, which contains accounts of the ecologic relations of each specimen collected while alive and is illustrated by many excellent photographs. As he granted me permission to use both his notes and photographs, I am publishing most of his notes, together with my remarks on the species collected by him, and am using several of his photographs as illustrations. His collection is now a highly valued part of the material belonging to the U. S. National Museum.

The third collection considered in this paper was made in 1914, by Mr. Carl Elschner, at Fanning Island, and comprises about 28 specimens (representing 26 species). This is valuable as filling a gap existing between our knowledge of the Hawaiian fauna and that of the islands south of the equator in nearly the same longitude. The specimens, which were sent to me by Professor W. A. Bryan with a request for their identification, are now the property of the U. S. National Museum; but a duplicate set is in the Museum of the College of Hawaii at Honolulu. Dr. Fred Baker had previously collected two species of *Acropora* at Fanning Island, one of which was again obtained by Mr. Elschner.

The three collections here considered help to extend our knowledge of the zoogeographic relations of the Indo-Pacific Madreporarian faunas. Previous to this paper, there were only scattered notes on the corals at Cocos-Keeling; there was no comprehensive account of the Australian fauna; and nothing was known of that of Fanning Island. The areas are well situated for a zoogeographic study. Cocos-Keeling Islands are in the eastern Indian Ocean, south of the west end of Sumatra, in latitude about 7° 30′ N.; Murray Island is at the east end of Torres Strait; Fanning Island is due south of the Hawaiian Islands, in latitude 3° 51′ 25″ N. The close affinities of the coral faunas of three areas are obvious in the table showing geographic distribution (pp. 64-66).

The zoogeographic relations of the Indo-Pacific coral faunas and the character of Atlantic coral faunas are considered in a manuscript which is

[1] Proc. Zool. Soc. London for 1907, pp. 518-556, pls. 27-29, 1907. [2] Lovell Reeve & Co., Ltd., London, 1910.

now nearly complete, and in it I discuss the relations of the living to the fossil faunas, especially those of Tertiary age.[1] In order to obviate duplicate publication I have omitted these topics from this paper, except to present in tabular form the information on the species actually considered herein. I am not giving a summary of present knowledge of the Cocos-Keeling or Australian corals, as when I do that I wish to compare them with other Indo-Pacific faunas. I am also omitting a summary of the ecologic information obtained through these studies, as a manuscript on the ecology of modern coral faunas is nearly ready for press, and in order to make it comprehensive any summary or general conclusions presented here would have to be republished. Furthermore, as Dr. Mayer's paper, which precedes this one, discusses in detail the ecology of the corals on the Murray Island reef, I could only supplement his account of them by considering some factors to which he does not pay special attention.

Some remarks should be made on the material available for comparison in the preparation of this paper. The collection of living species of corals in the U. S. National Museum is one of the largest in the world, and is probably second only to that of the British Museum (Natural History). The first two important collections which came into its possession are: (1) that of the U. S. Exploring Expedition under Charles Wilkes, U. S. Navy, which was the basis of Dana's classic volume on Zoophytes; (2) that of the North Pacific Exploring Expedition, which was described by Verrill. Most of the types of the species described in these reports are in the U. S. National Museum.

During the past thirty years, or more, accessions have come from many sources, important among which are the collections made by the U. S. Fish Commission (later Bureau of Fisheries) steamer *Albatross*. The area covered by this ship in its operations is enormous. An appreciation of how much has been accomplished aboard it may be obtained from C. H. Townsend's "Dredging and other operations of the United States Fish Commission steamer *Albatross*, with bibliography relating to the work of the vessel."[2] This record extends through the cruise under the direction of Mr. A. Agassiz in the Tropical Pacific in 1899-1900. Corals were collected in the western Atlantic Ocean and in the Pacific Ocean east of the longitude of the Marshall and Ladrone Islands, and were deposited in the U. S. National Museum. At one time I intended specially reporting on the collection of Pacific corals made in 1899–1900, but after an examination it seemed to me scarcely to warrant such treatment, as nearly all the specimens belong to well-known species. I now believe an account of it should be published, as a large part of the material comes from areas, especially the Paumotus, farther east in the Pacific than those usually visited. I have critically identified nearly all of it, and have used it in the preparation of this paper.

[1] A summary of the geologic history of the Tertiary and Quaternary coral faunas of the southeastern United States, the West Indies, and Central America is contained in Professional Paper 98-T, U. S. Geological Survey, pp. 361–367, 1917.

[2] U. S. Fish Com. Rep. for 1900, pp. 387–562, pls. 1–7, 1901.

The *Albatross* collection, made in the Hawaiian Islands in 1902, was the incentive to my "Madreporaria of the Hawaiian Islands and Laysan," but Professor W. T. Brigham greatly added to the suites of reef corals. That paper was based on the study of about 2,000 specimens, nearly all of which are in the U. S. National Museum. Only a few corals were obtained in the eastern Pacific in 1904–1905, but I reported on them in a paper cited in the bibliography on page 61.

The collections from the Philippine Islands are large. In 1901 about 3,000 specimens were purchased from Mr. J. B. Steere; the *Albatross*, besides the dredged material, obtained a number of shoal-water corals in 1907–1908; and numerous small lots have been received from army and navy officers and other persons, among whom Col. E. A. Mearns and Mr. Albert M. Reese should be specially mentioned. The collection made by Mr. Reese at Mariveles, Luzon, is good and appears to represent well that locality. I have, while studying material from other localities, worked over most of these collections except the Perforata, of which I have identified only a few species.

In addition to the collections already mentioned, there are many smaller ones. Among these is one made by Dr. W. L. Abbott in the western Indian Ocean, probably at Aldabra.

An inspection of this list shows that, although the collections from the Pacific area (including the Philippines and the Fiji Islands and eastward from them) are large, there was in the U. S. National Museum almost nothing from Australia; from the Indian Ocean there were only the small lot obtained by Dr. Abbott near Aldabra and some duplicates from French Somaliland, received from Dr. Charles Gravier; and there still is very little from the Red Sea. The deficiencies for Australia and the Indian Ocean are largely remedied by the collections received from Dr. Mayer and Dr. Wood Jones. Professor Stanley Gardiner has sent to the U. S. National Museum a set of corals, labeled by Mr. George Matthai, representing most of the species described by the latter in his paper entitled, "A revision of the recent colonial Astræidæ possessing distinct corallites."[1] This is valuable for our collections, as the specimens come from the Indian Ocean or the Red Sea, and because by having them I am able to understand more definitely Mr. Matthai's text and figures.

The general collections of the Museum have been utilized in making comparisons, and in a few instances I have incorporated descriptions of species from localities not indicated in the title of this paper; an instance is *Favia matthaii*, from the western Indian Ocean, probably Aldabra. As this is primarily a zoogeographic study, I have felt it germane to include any material, so far as practicable, which would aid in achieving its purpose. I have, therefore, endeavored to supplement Mr. Matthai's paper, just referred to, by including descriptions and figures of Dana's and Verrill's types, whenever it seemed desirable for a better understanding of the subject.

[1] Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, part 1, pp. 1–140, 38 pls.

The customary remarks about the unsatisfactory condition of the classification of the Madreporaria will be repeated. Certain of the groups, it seems, are natural, for instance, the Fungiidæ, the Eupsammiidæ, the Acroporidæ, and the Poritidæ; but the classification of other groups, especially the so-called Astræidæ, is in a highly unsatisfactory condition. Mr. Matthai's is the last attempt at classifying them. Although he has rendered valuable service in describing the anatomy of a number of corals and in publishing many good illustrations, especially of the types of species, he has, in my opinion, not only not established that the corals considered by him may be classified according to their genetic relations on the basis of the character of the directive mesenteries, but the placing of such species as *Orbicella versipora*, *Favia stelligera*, and *Acanthastrea echinata* in the same genus (*Favia*) appears to me to invalidate such a method. I am therefore splitting his genus *Favia* into three families, distributing the species among four genera, and am suggesting that a fifth genus may be represented. The basis of the classification I am using should be made evident. Besides some characters obvious to all students of the groups, I am utilizing the method of asexual reproduction and the character of the septal margins. It seems to me that each subgroup of corals may reproduce by gemmation and by fission. For instance, *Orbicella annularis* reproduces by gemmation, while *Favia fragum* forms new corallites by fission, but they are more closely related to each other than is either to *Mussa angulosa*, which in its reproduction resembles *Favia*. According to my treatment, *Orbicella* and *Favia* belong to different families within the same superfamily; whereas *Mussa* belongs to another family, but, as at present only one family with its peculiar septal characters is known, there is no known group of genera to form a superfamily.

The system of classification I am using is only tentative and needs critical testing, as do all systems. A searching study of the septal structure of all the mussoid genera and of many of the species is one of the essentials for such a test; and the results of such an investigation should be compared with the results from similar studies of the septal structure of *Orbicella*, *Favia*, and *Favites*. Perhaps the criteria on which I am basing families will not stand such a test.

A classification to be valid must be phylogenetic, and for that we must strive. M. Dollfus in 1906[1] closed a review of my paper on the simple genera of the Madreporaria Fungida with the statement:

> "Nous ne ferons qu'une critique, unique mais importante, à cette classification, c'est qu'elle n'a rien de phylogénétique; les espèces et les genres de tous les temps et de tous les pays y sont mélangés, aucun caractère évolutif n'apparaît. C'est peut-être que la perforation des cloisons[2] qui lui sert de base principale, est au fond un caractère secondaire, tandis que certaines modifications laissées dans l'ombre devraient être, au contraire, considerées comme des symtômes prépondérants et nous donneraient le tableau de la marche de la vie dans tout le groupe, ce qui nous manque jusqu'ici absolument."

[1]Rev. crit. de Paléozool., 10 An., No. 1, pp. 65–67, 1906.

[2]See my paper on Hawaiian corals, pp. 127–128, 139–140. M. Dollfuss is correct in his surmise.

This criticism is just, and because I was aware of the defect so rightly emphasized I designated the classification "tentative." The principle on which M. Dollfus insists must be the guiding one. It is my conviction that any attempt to base a classification of corals on living forms alone is foredoomed to failure. The forebears as well as the children must be studied. Since the genera *Orbicella*, *Favia*, and *Favites* are as clear-cut in the Oligocene and upper Eocene of the West Indies as they are in the modern faunas of Cocos-Keeling Islands, their phylogeny will probably not be ascertained by a study of living species. *Orbicella* and *Favia* persist in the living West Indian faunas, but *Favites* is not known in the Atlantic Ocean.

As regards the delimitation of species, Mr. Matthai and I are nearly in agreement; but as he has not followed the accepted rules of nomenclature, many of the names used by him are invalid. In some instances, the names applied by him are antedated by those proposed by Dana; but until he had examined the types, he could not be sure of Dana's species. I have made most of the needed revisions in the systematic discussion of the species.

There is one point which can scarcely be too strongly emphasized, especially as it is so often neglected by workers on corals. *Genera must be based on type species.* The neglect of this matter by modern workers is remarkable, as Fischer de Waldheim designated a type species for *Hydnophora* and Milne Edwards and Haime endeavored to ascertain or to designate one for nearly every genus considered by them. I am either giving the previously determined type species, or, when none has been determined, I am designating one for every genus herein considered.

The photographs used in illustrating this paper are from various sources. Dr. Wood Jones has furnished several; a few, from negatives made through the kind offices of Professor J. Graham Kerr, of the University of Glasgow, illustrate the types of Ellis and Solander; the U. S. National Museum has supplied most of the photographs of Dana's types; and the U. S. Geological Survey has contributed six photographs of Dana's types and the two photomicrographs of *Cœloseris mayeri*. All the other illustrations were supplied by the Carnegie Institution of Washington. There are about 340 of these, of which 80 were made by Miss L. B. Gallaher in the photographic laboratory of the U. S. National Museum, and about 260 were made by Mr. W. O. Hazard, of the U. S. Geological Survey.

I wish to thank Dr. George Otis Smith, Director, and Mr. David White, Chief Geologist, of the U. S. Geological Survey, for the interest they have taken in this paper, and the encouragement and assistance they have given me. It has been prepared as a part of my duties as an officer of the Survey, which has also furnished the requisite clerical assistance and the services of a preparator in caring for and handling the collections.

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The following list contains the titles of my publications on corals, the geology of coral-reef areas, and geologic processes associated with coral reefs, except that my papers on stratigraphic geology, for instance, those on the geology of northwest Louisiana, in which only incidental mention of corals is made, are not included. The supplemental list of papers contains the titles of those written by other investigators, either at my suggestion or under my direction.

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GEOGRAPHIC DISTRIBUTION OF SPECIES.

The following table shows the geographic distribution of the species described in this memoir. There is a column each for the collections made at Cocos-Keeling by Dr. Wood Jones, at Murray Island by Dr. Mayer, and at Fanning Island by Mr. Carl Elschner. In the last column the distribution especially in other areas is indicated. By comparing the four columns it will be seen that a number of the species, although not collected at Murray Island, probably occur in the Great Barrier Reef area, for they have been found west of it in the Indian Ocean and east of it in the Pacific Ocean. It is therefore probable that, with few exceptions, all the species described in this paper are to be found in the Great Barrier Reef area.

The total known fauna of the Great Barrier Reef may be compiled by taking the list for Murray Island and supplementing it by the names of species given under *Astreopora*, *Turbinaria*, *Montipora*, and *Acropora*. To these names should be added those contained in Quelch's report on the *Challenger* corals, unless already included. The list published by Saville-Kent is of very little value, as it is to a considerable degree only a heterogeneous assemblage of names, many of which do not apply to any Australian corals. A complete list of the Australian coral faunas, as at present known, is not here published, for reasons already stated.

Geographic distribution of species considered in this paper.

Name.	Cocos-Keeling.	Murray Island.	Fanning Island.	Distribution.
Seriatopora hystrix Dana		×		Amboina; Fiji Islands.
angulata Klz	×			Red sea; Indian Ocean.
Pocillopora bulbosa Ehr.	×	×		Indian Ocean; Pacific, east to Fiji Islands.
damicornis (Pal.)	×		×	Indian Ocean; Pacific, east to Fanning Island.
danæ Verrill		×		Philippines; Fiji Islands.
verrucosa (Ell. & Sol.)	×			Indian Ocean; Pacific, east to Fiji Islands.
meandrina Dana			×	Hawaiian Islands.
elegans Dana	×			Pacific; east to Fiji Islands.
eydouxi M. Edw. & H.	×	×		Pacific; Funafuti; Rotuma.
woodjonesi, new species	×			
Stylophora pistillata (Esper)		×	×	Red Sea; Indian Ocean; Pacific, east to Fanning Island.
mordax (Dana)			×	Fiji Islands.
Acrhelia horrescens (Dana)		×		Fiji Islands.
Euphyllia glabrescens (Cham. & Eys.)		×		Indian Ocean; Pacific, east to Fiji Islands.
fimbriata (Spengler)				Maldives; Australia; East Indies; Amboina.
Orbicella versipora (Lam.)	×			Indian Ocean; Seychelles eastward; Australia.
gravieri, new species				French Somaliland.
curta Dana		×		Pacific, east to Paumotos.
Cyphastrea microphthalma (Lam.)	×			Red Sea; Indian Ocean; Philippines
serailia (Forsk.)		×		Red Sea; Indian Ocean; Philippines; Kermadec Islands.
Leptastrea purpurea (Dana)	×	×	×	East Africa to Hawaiian Islands.
transversa Klz.			×	East Africa to Fanning Island.
bottæ (M. Edw. & H.)	×			East Africa to Hawaiian Islands.
immersa (Klz.)	×			Red Sea; Indian Ocean.
Echinopora lamellosa (Esper)	×			Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
Galaxea fascicularis (Linn.)		×		Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
clavus (Dana)				Ceylon; Maldives; Torres Strait; Pacific, east to Fiji Islands.
Favia stelligera (Dana)	×		×	Red Sea; Indian Ocean; Pacific, east to Fanning Island.
var. fanningensis, new var.			×	
speciosa (Dana)	×	×	×	From east Africa to Fanning Island.
pallida (Dana)		×		Indian Ocean; Maldives; Pacific, east to Fiji Islands.
danæ Verrill				Tongatabu.
matthaii, new species				Indian Ocean, Aldrabra(?).
Favites abdita (Ell. & Sol.)	×	×		Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
halicora (Ehr.)		×	×	Red Sea; Indian Ocean; Pacific, east to Fanning Island.
virens (Dana)		×		Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
pentagona (Esper)				French Somaliland; Maldives.
melicerum (Ehr.)	×			Red Sea; Indian Ocean; New Hebrides.
spectabilis (Verrill)				East Indies; Philippines.
Goniastrea parvistella (Dana)				Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
retiformis (Lam.)		×		Red Sea; Indian Ocean; Pacific, east to Wake Island and Fiji Islands.
pectinata (Ehr.)		×		Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
planulata M. Edw. & H.				Red Sea; Indian Ocean.
benhami Vaughan				Kermadec Islands; Formosa.
Leptoria phrygia (Ell. & Sol.)	×			Indian Ocean; Philippines.
gracilis (Dana)		×		Red Sea; Indian Ocean; Fiji Islands.
tenuis (Dana)				Southern Philippines; Fiji Islands.
Mæandra dædalea (Ell. & Sol.)		×		Indian Ocean; Pacific, east to Paumotus.
lamellina (Ehr.)		×	×	Red Sea; Indian Ocean; Pacific, east to Fanning Island.

Geographic distribution of species considered in this paper—continued.

Name.	Cocos-Keeling.	Murray Island.	Fanning Island.	Distribution.
Mæandra astreiformis (M. Edw. & H.)		×		Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
stricta (M. Edw. & H.)		×		Australia; southern Philippines.
Hydnophora exesa (Pall.)	×	×		Red Sea; Indian Ocean; Pacific, to southern Philippines.
microconos (Lam.)	×	×	×	Red Sea; Indian Ocean; Pacific, east to Fanning Island.
rigida (Dana)			×	Great Barrier Reef; southern Philippines; Fiji Islands; Fanning Island.
Mussa sinuosa (Lam.)		×		Red Sea; Pacific, east to Tahiti.
Symphyllia nobilis (Dana)		×		Maldives; Singapore; Pacific, east to Rotuma.
Acanthastrea echinata (Dana)		×		Red Sea; Indian Ocean; Pacific, east to Paumotus.
Merulina ampliata (Ell. & Sol.)				Maldives; Torres Strait; East Indies.
Fungia aff. F. concinna Verrill		×		Red Sea; Indian Ocean; Pacific, east to Jaluit and Samoa.
fungites (Linn.)	×	×		Red Sea; Indian Ocean; Pacific, east to Tahiti and Samoa.
scutaria (Lam.)	×		×	Red Sea; Indian Ocean; Pacific, east to Fanning Island and Hawaiian Islands.
Herpetolitha crassa Dana	×			Cocos-Keeling; Fiji Islands; Funafuti.
stricta Dana				Tahiti; Jaluit.
limax (Esper)				Red Sea; Singapore; southern Philippines.
Polyphyllia talpina (Lam.)		×		Singapore; Philippines; Amboina; Vanikoro.
Pachyseris speciosa (Dana)		×		East Indies; Australia; Fiji Islands.
torresiana, new species				Torres Strait.
Pavona cactus (Forsk.)				Red Sea; east to Tahiti.
venusta Dana				Locality not known.
danai (M. Ewd. & H.)	×			Red Sea; Indian Ocean; Philippines: Caroline Islands.
maldivensis (Gardiner)	×			Maldives; Cocos-Keeling Islands.
varians Verrill	×	×	×	Red Sea; Indian Ocean; Pacific, east to Fanning Island and Hawaiian Islands.
Cœloseris mayeri, new gen. and sp.		×		Australia; southern Philippines.
Agaricia ponderosa Gardiner				Minikoi; southern Philippines.
Psammocora gonagra Klz.		×		Red Sea; Indian Ocean; Murray Island.
haimiana M. Edw. & H.	×			Red Sea; Indian Ocean; Pacific to Funafuti.
sp	×			
profundacella Gardiner			×	Funafuti; Fanning Island.
Diploastrea heliopora (Lam.)				French Somaliland; Indian Ocean; Pacific, east to Fiji Islands.
Dendrophyllia nigrescens Dana		×		Red Sea; Indian Ocean; Pacific, east to Fiji Islands.
willeyi (Gardiner)	×		×	Indian Ocean; Pacific, east to Fanning Island.
manni (Verrill)			×	Fanning Island; Hawaiian Islands.
diaphana Dana	×			Singapore; Cocos-Keeling.
Astreopora myriophthalma (Lam.)	×		×	Red Sea; Indian Ocean; Pacific, east to Fanning Island.
ocellata Bernard		×		Australia.
Turbinaria crater (Pallas)				Torres Strait, Australia; Amboina; Kermadec Islands.
peltata (Esper)				Torres Strait, Australia; Indian Ocean; Malay Seas.
Montipora levis Quelch	×			Cocos-Keeling; Banda; Fiji Islands.
tortuosa (Dana)	×			Cocos-Keeling; Singapore.
ramosa Bernard	×	×		Cocos-Keeling; Murray Island; Amboina; Southern Philippines.
turgescens Bernard		×		Australia.
cocosensis, new species	×			Cocos-Keeling.
venosa (Ehr.)		×		Red Sea; Australia; Amboina; Fiji Islands.
spumosa (Lam.)	×			Cocos-Keeling; Australia; Tongatabu.

Geographic distribution of species considered in this paper—continued.

Name.	Cocos-Keeling.	Murray Island.	Fanning Island.	Distribution.
Montipora elschneri, new species	..	..	×	Fanning Island.
sp	×	..	..	Cocos-Keeling.
verrucosa (Lam.)	..	..	×	Australia to Fanning Island and Hawaiian Islands.
informis Bernard	×	..	..	Australia; Cocos-Keeling.
aff. M. informis Bernard	..	×	..	Murray Island.
verrilli Vaughan	..	..	×	Fanning Island; Hawaiian Islands.
foliosa (Pallas)	×	..	..	Indian Ocean; Amboina; Philippines; New Hebrides.
Acropora pulchra (Brook)	×	..	..	Cocos-Keeling.
var. alveolata (Brook)	..	×	..	Australia.
haimei (M. Edw. & H.)	..	×	..	Red Sea; Indian Ocean; Australia; Fiji Islands.
variety	..	×	..	Murray Island.
decipiens (Brook)	..	×	..	Great Barrier Reef.
abrotanoides (Lam.)	..	×	..	Singapore; Australia; Tahiti.
pharaonis (M. Edw.)	×	..	..	Red Sea; western Indian Ocean; Cocos-Keeling.
forma arabica (M. Edw.)	×	..	..	Red Sea; Indian Ocean.
corymbosa (Lam.)	×	..	×	Red Sea; Indian Ocean; Australia; Pacific, east to Fanning Island.
pectinata (Brook)	..	×	..	Australia.
spicifera (Dana)	×	..	..	Indian Ocean; Australia; Fiji Islands; Tongatabu.
squamosa (Brook)	..	×	..	Australia.
sarmentosa (Brook)	..	×	..	Australia.
hebes (Dana)	..	×	..	Australia; Fiji Islands.
digitifera (Dana)	..	×	..	Australia; Madagascar.
scherzeriana (Brüg.)	×	..	..	Red Sea; Indian Ocean.
gemmifera (Brook)	..	×	..	Australia.
ocellata (Klz.) var.	×	..	..	Red Sea; Indian Ocean
palifera (Lam.)	×	..	..	Indian Ocean; Philippines.
var. α (Brook)	..	×	..	Australia.
plicata (Brook)	..	×	..	Australia.
polymorpha (Brook)	..	..	×	Malacca; Fiji Islands; Fanning Island.
variabilis (Klz.)	×	..	..	Red Sea; Indian Ocean.
murrayensis, new species	..	×	..	Torres Strait.
squarrosa (Ehr.)	..	×	..	Red Sea; Australia.
rosaria (Dana)	..	..	..	Fiji Islands; reported from Australia.
syringodes (Brook)	..	×	..	Australia; Samoa.
Goniopora tenuidens (Quelch)	..	×	..	Australia; Amboina; southern Philippines.
Porites solida (Forsk.)	×	..	..	Red Sea; Indian Ocean.
lobata Dana	..	..	×	Fiji to Hawaiian Islands.
murrayensis, new species	..	×	..	Australia.
fragosa Dana	..	..	..	Fiji Islands.
australiensis, new species	..	×	..	Australia; southern Philippines.
mayeri, new species	..	×	..	Australia.
haddoni, new species	..	×	..	Australia.
somaliensis Gravier	×	..	..	Indian Ocean.
lutea M. Edw.	..	..	..	Fiji Islands.
limosa Dana	..	..	..	Fiji Islands; Funafuti.
viridis Gardiner	..	×	..	Fiji Islands; Australia.
densa, new species	..	×	..	Australia.
pukoensis Vaughan	..	..	×	Fanning Island; Hawaiian Islands.
lichen Dana	×	..	..	Indian Ocean; Fiji Islands.
andrewsi, new species	..	×	..	Australia; Fiji Islands; Tonga Islands.
cylindrica Dana	..	..	..	Fiji Islands.
nigrescens Dana	×	..	..	Indian Ocean; Fiji Islands.
Tubipora musica Linn	..	×	..	
Millepora dichotoma Forsk	×	..	..	
platyphylla Ehr.	×	..	..	
truncata Dana	..	..	×	

SOME CORALS FROM KERMADEC ISLANDS.

After submitting the manuscript for this volume for publication I have completed a short paper entitled "Some corals from Kermadec Islands," which has been transmitted for publication in the Transactions of the New Zealand Institute. The collection was made by Mr. W. R. B. Oliver in 1908, and was sent to me in 1910 by Professor W. B. Benham of Otago University, Dunedin, with a request that I report on it. As the geographic distribution of the species is interesting in this connection, a list of them with their geographic distribution is inserted below.

All the species are widely distributed Indo-Pacific corals; 5 of the 8 are known from eastern Australia, while another occurs both east and west of the Great Barrier Reef. Two of the species are known from the Philippines or Formosa, but as yet have not been authentically reported from Australia.

Geographic distribution of Kermadec Island corals.

Name.	Distribution.
Pocillopora bulbosa Ehrenb.	From Cocos-Keeling Islands to Fiji Islands, represented in the Hawaiian Islands by the closely related, if not specifically identical, *P. cespitosa* Dana.
Orbicella curta Dana	Great Barrier Reef, thence eastward to the Paumotus.
Cyphastrea serailia (Forskål)	Red Sea; Indian Ocean; Great Barrier Reef; Philippine Islands.
Goniastrea benhami Vaughan	Formosa; probably Singapore.
Leptoria tenuis (Dana)	Southern Philippines; Fiji Islands.
Sclerophyllia margariticola Klz.	Red Sea; western Indian Ocean.
Turbinaria crater (Pallas)	Torres Strait; Amboina.
Montipora caliculata (Dana) Bernard	Torres Strait; New Guinea; Macclesfield Bank; Kandavu.

CORALS FROM MURRAY ISLAND ACCORDING TO STATION.

The following lists include names of all species of corals which Dr. Mayer collected in the vicinity of Murray Island and submitted to me for determination. These lists are more complete than the one given in his discussion of the ecology of the Murray Island coral fauna, as he considers in his article only 37 species, while he actually obtained 63 species, not including varieties.

List of corals on and within 200 feet on both sides of line I, southeast reef, Murray Island, and distance from shore to place at which collected.

Name.	400 feet.	450 feet.	500 feet.	525–550 feet.	600 feet.	620 feet.	650 feet.	675–720 feet.	700 feet.	800–820 feet.	980 feet.	1000–1020 feet.	1200 feet.	1220–1250 feet.	1400 feet.	1445 feet.	1600 feet.	1620–1670 feet.	1720–1775 feet.
Seriatopora hystrix Dana							×			×	×	×	×		×				
Pocillopora bulbosa Ehr.	×				×					×			×		×		×		×
eydouxi M. Edw. & H.																			×
Stylophora pistillata (Esper)																			×
Acrhelia horrescens (Dana)												×							
Euphyllia glabrescens (Cham. & Eys.)					×					×		×							
Orbicella curta Dana																			×
Cyphastrea serailia (Forsk)					×							×					×		
Leptastrea purpurea (Dana)																		×	
Galaxea fascicularis (Linn)																	×		

List of corals from and near line I, southeast reef, Murray Island, etc.—Continued.

Name.	400 feet.	450 feet.	500 feet.	545–550 feet.	600 feet.	620 feet.	650 feet.	675–720 feet.	700 feet.	800–820 feet.	980 feet.	1000–1020 feet.	1200 feet.	1220–1250 feet.	1400 feet.	1445 feet.	1600 feet.	1620–1670 feet.	1720–1775 feet.
Favia speciosa (Dana)					×														
pallida (Dana)																			
facies 1																	×		
facies 2																	×		×
facies 3																		×	
facies 4																		×	
facies 5																			×
facies 6												×						×	×
Favites abdita (Ell. & Sol.)																		×	×
halicora (Ehr.)															×		×		
virens (Dana)																		×	
Goniastrea retiformis (Lam)				×									×	×			×		
pectinata (Ehr.)	×			×	×			×	×	×							×		
Leptoria gracilis (Dana)																	×	×	
Mæandra dædalea (Ell. & Sol.)																	×	×	
lamellina Ehr.																	×		
astreiformis (M. Edw. & H.)																		×	
stricta (M. Edw. & H.)																	×		
Hydnophora exesa (Pall.) (at 300 feet)																			
microconos (Lam.)																	×		×
Mussa sinuosa (Lam.)												×							
Symphyllia nobilis (Dana)																	×	×	
Acanthastrea echinata (Dana)																			×
Fungia aff. F. concinna Verrill																×			
fungites (Linn.)												×							
Polyphyllia talpina (Lam.)															×				
Pavona varians (Verrill)										×									
Cœloseris mayeri, new gen. and species	×				×		×			×		×						×	
Psammocora gonagra Klz.				×	×														
Astreopora ocellata Bernard														×				×	
Montipora turgescens Bernard																			×
venosa (Ehr.)															×			×	
aff. M. informis Bernard															×				
Acropora pulchra																			
var. alveolata (Brook)					×							×			×		×		
decipiens (Brook)																			×
abrotanoides (Lam.)													×						
haimei (M. Edw.)										×									
haimei (M. Edw.) var.															×				
pectinata (Brook)										×							×		
squamosa (Brook)												×			×		×		
sarmentosa (Brook)																	×		
hebes (Dana)					×					×			×		×				
gemmifera (Brook)																			×
digitifera (Dana)															×		×		
palifera (Lam) var. α (Brook)										×		×	×		×		×		×
plicata (Brook)															×		×		
murrayensis, new species																	×	×	
squarrosa (Ehr.)															×				
Goniopora tenuidens (Quelch)			×		×					×		×	×		×		×		
Porites australiensis, new species		×		×		×		×		×		×	×						×
haddoni, new species	×					×		×											
murrayensis, new species	×				×		×						×						
mayeri, new species					×		×	×		×		×	×	×	×		×		
viridis Gardiner					×							×							
densa, new species																	×		
andrewsi, new species	×				×		×			×			×						
Tubipora musica L	×				×					×		×					×		

In the following table the number of species given for each station represents the number actually submitted, *plus* certain interpolations. If a species was collected at 800 feet and 1,200 feet from shore, but not at 1,000 feet, it is added to the list of those from 1,000 feet, as not finding it at that station was probably accidental.

Distance from shore, depth of water, character of bottom, number of species, and growth-form of the colonies, for each station on line I, southeast reef, Murray Island.

Distance from shore.	Depth of water at low tide in inches.	Character of bottom.	No. of species at each station.	No. of species according to growth-form.		
				Fragile branches and free disks.	Stout branches.	Massive or incrusting.
300 feet	2 to 4	Hard limestone mud over lava rock	1	..	..	1
400 feet	4.5 to 5	Firm limestone mud	7	3	..	4
450–550 feet	6 to 12	Sand and mud, rock	10	3	.	7
600–650 feet	6.5 to 10	Sandy	18	7	..	11
800–820 feet	10 to 11	Broken coral	[1]20	6	1	12
1000–1020 feet	14 to 17	Rocky	21	10	1	10
1200–1250 feet	12 to 16	Rocky	18	6	2	10
1400–1445 feet	14 to 15	Rocky, broken coral	24	10	2	12
1600–1675 feet	10 to 16	Hard, rocky, broken coral	32	4	2	26
1720–1775 feet	2.5 to 3	Hard, rocky, with crevice-like tide pools.	13	..	6	7

[1]*Acropora pectinata* (Brook), which is of discoid-corymbose growth-form, is not counted in the tabulation.

Although there are corals of massive growth-form up to within 300 feet of shore, and they somewhat preponderate in the number of species, they reach their greatest development near the outer edge of the reef at 1,600 feet from shore and beyond, while the maximum number of species with fragile branches is between 1,200 and 1,445 feet from shore, and there is none on the exposed seaward face of the reef. These relations of growth-form to position on the reef are dependent primarily on capacity to resist waves and surf. Fragile corals would be smashed on the outer edge of the reef. Massive as well as fragile forms may live in quiet water if sediment should not be deposited on their surfaces more rapidly than it can be removed.

OTHER CORALS COLLECTED NEAR MURRAY ISLAND.

Montipora ramosa Bernard was collected on line II, off the middle of the northwest side of the island, at 150 feet from shore, on a firm sandy bottom, covered with *Posidonia* and bare at low tide, and under a similar environment on the same line, at 180 feet from shore; also on line III, off the north end of the island, at 1,150 feet from shore, on a firm bottom of mud and volcanic sand, covered with grass, and bare at low tide. This coral has the same growth facies as *Porites furcata* and *Porites divaricata*, which live under similar environmental conditions (protected shallow flats, where there is often much grass) in Florida and the West Indies.

Pocillopora danæ Verrill was collected on the outer edge of the south reef of the island, where there is a strong tidal current, in a place almost awash at lowest tide, and subject to strong seas. Although of not especially delicate structure, the colony is ramose, and one would not think that it could withstand the beating of heavy surf.

Two fine colonies of *Acropora gemmifera* (Brook) were obtained from the inner side of a reef patch on the Great Barrier Reef, 6 miles east by north from Murray Island, in water 3 to 4 feet deep at low tide (see plate 77, figures 1, 1*a*, 2, 2*a*). A considerable area of the base of one specimen is covered by an incrustation of *Cyphastrea serailia*, and there is a great deal of *Polytrema mineaceum* (Linn.), as well as crustaceous lithothamnion. Another specimen of *A. gemmifera* was collected on the inner edge of one of the patches on the Great Barrier Reef, 6 miles east of Murray Island, in water about 4 feet deep, where there is a strong current and within the zone of breakers. This is the specimen represented by plate 77, figures 3, 3*a*. *A. gemmifera* is a tremendously strong coral, entirely adapted to life on exposed reefs.

The following species were obtained from depths of 15 to 18 fathoms, off northwest reef, Murray Island:

Stylophora pistillata (Esper), 18 fathoms.
Pachyseris speciosa (Dana), 15 fathoms.
Dendrophyllia nigrescens Dana, 18 fathoms.
Acropora syringodes (Brook), 18 fathoms.

These are all fragile forms and could not exist in the zone of breakers, but the required conditions are met by living at depths too great to be affected by breakers.

CORALS FROM COCOS-KEELING ISLANDS.

Dr. Wood Jones has given two accounts of this collection in publications referred to on page 55, but the species represented had not then been determined.

List of corals obtained by Dr. Wood Jones in Cocos-Keeling Islands and their habitat.

br. = branching; frag. = fragile; msv. = massive; pl. = plate; incrust. = incrusting.

Name of species and growth-form.	Habitat.		
	Lagoon.	Barrier pools and barrier flat.	Exposed barrier.
Seriatopora angulata Klz., delicately branched	×	..	..
Pocillopora bulbosa Ehr., br., form depends on environment, see p. 76	×	..	..
damicornis (Esper), br., rather strong	×	×	..
verrucosa (Ell. and Sol.), stout br	..	..	..
elegans Dana, strong br., aborted on surf	×	..	×
eydouxi M. Edw. and H., br., rather strong	×	..	..
woodjonesi, new species, br., rather strong	..	×	..

List of corals obtained by Dr. Wood Jones in Cocos-Keeling Islands and their habitat—Con.

br. = branching; frag. = fragile; msv. = massive; pl. = plate; incrust. = incrusting.

Name of species and growth-form.	Habitat.		
	Lagoon.	Barrier pools and barrier flat.	Exposed barrier.
Orbicella versipora (Lam.), msv	..	..	×
Cyphastrea micropthalma (Lam.), msv	..	×	..
Echinopora lamellosa (Esper), thin folia	×	..	..
Leptastrea purpurea (Dana), msv	..	×	..
bottæ (M. Edw. and H.), msv	×	×	..
immersa Klz., msv	..	×	..
Favia stelligera (Dana), msv	×	×	×
speciosa (Dana), msv. (dead specimen)	..	..	..
Favites abdita (Ell. and Sol.), msv	×	..	..
melicerum (Ehr.), msv. (dead specimen)	..	..	..
Leptoria phrygia (Ell. and Sol.), msv	×	..	..
Hydnophora microconos (Lam.), msv. (dead specimen)	..	..	..
exesa (Pall.), lobate	..	..	..
Fungia fungites (Linn.), free disk	×	×	..
scutaria (Lam.), free disk	..	×	..
Herpetolitha crassa Dana, free coral	×	..	..
Pavona danai (M. Edw. and H.), strong folia	×	..	..
maldivensis (Gardiner), msv	..	Lagoon edge of barrier.	..
varians Verrill, msv	..	×	..
Psammocora haimiana M. Edw. and H., msv	..	×	×
sp., incrust	Sand flats	..	..
Dendrophyllia willeyi (Gardiner), msv	..	..	×
diaphana Dana, incrust. base, protub. corallites	..	..	×
Astreopora myriophthalma (Lam.), msv	..	×	..
Montipora levis Quelch, br	×	..	..
tortuosa Dana, frag., br	×	..	..
ramosa Bernard, frag., br	×	Especially inner margin	..
cocosensis, new species, br	..	Lagoon side	..
spumosa (Lam.), msv	..	..	×
sp., lobate columns	..	Lagoon side	..
informis Bernard, msv., pl. on lower edges	..	..	×
foliosa (Pallas), thin folia	×	..	..
Acropora pulchra (Brook), frag., br	×	..	..
pharaonis (M. Edw. and H.), br	×	×	..
forma arabica (M. Edw. and H.)	..	..	..
corymbosa (Lam.), corymbose	Lagoon inlet	..	..
spicifera (Dana), corymbose	..	×	..
scherzeriana (Brueg.), msv. base, stout br	..	..	×
ocellata (Klz.) var., msv., lobate	..	..	×
variabilis (Klz.), br	..	×	..
palifera (Lam.), strong br	×	..	×
Porites solida (Forsk.), msv	..	..	×
somaliensis Gravier., msv	..	..	×
lichen Dana., incrust	..	..	×
nigrescens Dana, br	×	..	..
Millepora dichotoma Forsk., br	..	Inner margin of barrier	..
platyphylla Ehr., strong folia	..	..	×
sp., incrust	..	..	×
Total number of species according to locus	23	20	16

The data concerning four of the species listed in the preceding table are deficient.

The species may be arranged so as to indicate more clearly the relation of growth-form to environment:

Relations of growth-form of Cocos-Keeling corals to habitat.

Habitat.	Free corals.	Fragile branches or folia.	Stout branches and lobate columns.	Growth-form massive.
Lagoon	2	11	5	5
Barrier pools and barrier flat	2	6 (mostly on lagoon edge of flat).	4	8
Exposed side of barrier	0	0	3	13

This table shows precisely the same relation of growth-form to habitat as do the corals from Murray Island.

SYSTEMATIC DISCUSSION OF THE SPECIES.

Class ANTHOZOA.

Subclass ZOANTHARIA Milne Edwards and Haime.

Order HEXACORALLA Haeckel.

MADREPORARIA IMPERFORATA.

Family SERIATOPORIDÆ Milne Edwards and Haime.

1849. *Seriatoporidæ* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 29, p. 262.
1869. *Pocilloporidæ* Verrill, Proc. Essex Inst., vol. 6, p. 90.

As I see no valid reason for referring *Seriatopora* and *Pocillopora* to different families, these genera are placed in the Seriatoporidæ, a name twenty years older than Verrill's Pocilloporidæ. While seriously doubting the propriety of placing *Stylophora* in a separate family, as the similarity between it and *Seriatopora* is great, I adhere to the traditional usage.

Genus SERIATOPORA Lamarck.

1816. *Seriatopora* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 282.
1849. *Seriatopora* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 29, p. 262.

Type species: *Seriatopora subulata* Lamarck.

Unfortunately this species, the type of the genus, has not been figured or adequately described. As the type specimen of the species is in the Muséum d'Histoire Naturelle in Paris, it is hoped that these desiderata may be supplied.

Seriatopora hystrix Dana.

Plate 20, figures 1, 1*a*, 1*b*, 1*c*, of specimen from Murray Island; figures 2, 2*a*, of Dana's type. Also plate 2, figure 4, of Dr. Mayer's article.

1846. *Seriatopora hystrix* Dana, U. S. Expl. Exped., Zooph., p. 521, plate 19, figs. 3, 3*a*, 3*b*.
1907. *Seriatopora hystrix* Bedot, Madréporaires d'Amboine, p. 154, plate 7, figs. 18–22.

The following notes are based on specimen No. 346, U. S. National Museum, from the U. S. Exploring Expedition collection. This seems to be Dana's type, for his original label is still preserved. Plate 20, figure 2, represents part of the colony, which is of bushy shape, 18.5 cm. wide and about 15 cm. tall. Diameter of branches near the base, 5 to 6 mm; diameter of one branch 40 mm. from the apex, 5.5 mm.; diameter of another 21 mm. from apex, 3.6 mm. Calices in rather definite rows, 6 to 9 on a branch, diameter about 0.6 mm.; upper margin slightly protuberant, lower margin faintly developed or obsolete. Six well-developed septa. Columella thick, compressed in the plane of the directive septa. Cœnenchyma dense, surface thickly beset with small granulations.

The largest of the Murray Island specimens (plate 20, fig. 1) is a cluster 17 cm. in diameter and about 12 cm. high. Branches 5 to 6 mm. in diameter near the

base, above which they diverge, subdivide, and often interfuse. The following table, which shows the measurements of branches of *Seriatopora hystrix*, indicates the relative attenuation:

Measurements of branches of Seriatopora hystrix.

No.	Length.	Diameter at lower end.	Diameter just below apex.
	mm.	*mm.*	*mm.*
1	44.0	3.75	2.5
2	35.0	4.00	2.5
3	37.5	4.75	2.5
4	32.0	3.75	1.75
5	32.5	4.25	....
6	23.5	3.00 by 4.00	1.5 by 2.0
7	18.0	3.00	1.75

The measurements indicate very gradual decrease in diameter and that the apices are short conical or even obtuse (see plate 20, figs. 1*a*–1*c*). The arrangement and size of the calices are adequately shown in the figures. The calicular margins are slightly elevated, less prominent on the lower side of the calice. Six septa are obvious, the directives strongly developed. The columella is prominent, compressed in the plane of the directives. Cœnenchyma dense, surface finely echinulate.

The specimen on which the preceding description is based was collected 980 feet from shore. Specimens farther out on the flat show some variation, probably induced by rougher water.

Stations, Murray Island.—Southeast reef, line I:

650 feet from shore, rather loosely branched, fragile.
800 feet from shore, spreading clump, fragile.
980 feet from shore, spreading clump, fragile.
1,000 feet from shore, branches of about usual thickness but somewhat more crowded, much coalesced, making a stronger structure than in the colonies nearer shore.
1,200 feet from shore, (*a*) branches rather short, divergent, corallum fairly strong, (*b*) branches thinner, corallum fragile.
1,400 feet from shore, branches rather short, very crooked, with many aborted branchlets, environment evidently unfavorable.

Distribution.—Fiji Islands (type); Amboina (Bedot); Murray Island, Australia.

Seriatopora angulata Klunzinger.

Plate 20, figures 3, 4.

1879. *Seriatopora angulata* Klunzinger, Korall. Roth. Meer., pt. 2, p. 73, plate 10, fig. 14.
1906. *Seriatopora angulata* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 78, plate 28, figs. 107–112; plate 29, figs. 107*a*–112*a*, 115.
1910. Colorless *Stylophora* Wood Jones, Coral and Atolls, p. 97, text-fig. 31.

As von Marenzeller has so fully considered this species, a redescription is superfluous.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones has submitted two specimens which show variation in response to habitat. He makes the following notes:

Specimen with attenuate branches (plate 20, fig. 3), "lives only in the lagoon, appears to be altogether absent from the barrier or any water at all rough; depth 4 to 5 fathoms; not

abundant. Zooid pale yellow." Specimens with thicker, less attenuate branches (pl. 20, fig. 4), "from shallower water on the southern side of the lagoon, color pale brown, the zooid pale yellow."

Distribution.—Red Sea; Indian Ocean.

Genus POCILLOPORA Lamarck.

1816. *Pocillopora* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 273.
1849. *Pocillopora* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 29, p. 261.

Type species: *Pocillopora acuta* Lamarck.
The following species are considered in this paper:

Pocillopora bulbosa Ehrenberg; Murray Island; Cocos-Keeling.
damicornis (Pallas) Dana; Cocos-Keeling; Fanning Island.
danæ Verrill; Murray Island.
verrucosa (Ell. and Sol.) Lam.; Cocos-Keeling.
meandrina Dana; Fanning Island.
elegans Dana; Cocos-Keeling.
eydouxi M. Edw. and H.; Cocos-Keeling.
woodjonesi, new species; Cocos-Keeling.

As incidental to describing the species of *Pocillopora* and their variants found in the Hawaiian Islands,[1] most of the Pacific representatives of the genus were reviewed, reference may be made to that paper and the information contained in it need not be repeated here. As there is a definite order, which I trust is obvious, in the succeeding arrangement of species, a synoptic table seems unnecessary.

Pocillopora bulbosa Ehrenberg (fide Dana).

Plate 21, figures 1, 1*a*, specimen identified as *P. bulbosa* by Dana. Also plate 12, figures 1, 2, 3 of Dr. Mayer's article.

1846. *Pocillopora bulbosa* Dana, U. S. Expl. Exped., Zooph., p. 527, plate 49, figs. 5, 5*a*.
1907. *Pocillopora acuta* Bedot, Madréporaires d'Amboine, p. 152, plate 7, figs. 14–17.
1907. *Pocillopora* Wood Jones, Proc. Zool. Soc. London for 1907, p. 536, plate 28, fig. 3.
1910. *Pocillopora* Wood Jones, Coral and Atolls, p. 99, text-fig. 31.

There is much confusion regarding the names *damicornis* and *bulbosa*, as the former name proposed by Pallas included an aggregation of forms now divided into a number of species. Lamarck (1816) refers to Esper (Fortsetz., plates 46 and 46*a*), as illustrating *damicornis*; Dana refers to plate 47 of Esper (Fortsetz.), as representing *damicornis*, and to plate 46 of the same work as *P. bulbosa*. Milne Edwards accepts Dana's identifications, but refers Esper's plate 46*a* (Fortsetz.) to *P. damicornis*, wherein he differs from Dana, but both agree on *P. bulbosa*. Regarding the latter, Milne Edwards says: "Ce polypier pourrait bien ne pas être distinct spécifiquement du *P. damicornis*." It therefore appears that *P. bulbosa* Ehrenberg is a synonym of *P. damicornis* (Pallas) (emend. Lamarck), and that the *damicornis* of Dana (Esper, Fortsetz., plate 47) should receive another name; but a positive decision can not be reached until Lamarck's original specimens are restudied. As the original specimens of Dana's *P. bulbosa* and *P. damicornis* are in the U. S. National Museum, I am following his usage. In his treatment of *P. bulbosa* he is in accord with Milne Edwards, but the similarity between it, *P. cespitosa* Dana,[2] and *P. acuta* Lamarck is so great that the three may belong to the same species. Dana and Milne Edwards appear to disagree regarding *P. damicornis*.

Stations, Murray Island.—Southeast reef, line I, 400, 600, 800, 1,200, 1,400, and 1,600 feet from shore, and Lithothamnion ridge.

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[1]U. S. Nat. Mus. Bull. 59, pp. 84–199, 1907.
[2]See Vaughan, U. S. Nat. Mus. Bull. 59, pp. 86–91, plate 10, figs. 1, 1*a*, 2, 2*a*; plate 11, figs. 1, 2, 1907.

The Murray Island specimens show response to environmental conditions similar to that exemplified by the specimens from Cocos-Keeling. All except those from the Lithothamnion ridge have relatively attenuate branches, while those from it have the *brevicornis* growth facies. But on those of the latter facies between the thicker branches and peripherally below them there are some more slender branches. This response to smooth and rough water is general where the same species of a branching coral lives in the two kinds of environment. I have noted it in discussing the Hawaiian corals, and instances (especially *Porites clavaria*) were observed in Florida.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones has submitted 6 specimens taken from a floating log. He has published two accounts of them.[1] In the first of the citations he says:

> "In the lagoon, a large portion of a tree-trunk was floated, and made fast to an anchor and chain; the wood was used to float a ship's moorings, and remained just two years in the water. When it was removed in 1906, several colonies of *Pocillopora* had started growths upon it, and they had taken up different positions around its circumference. The colonies growing above were flattened bosses; those on the sloping sides showed more tendency to branch; and those below its convexity were delicate branched forms.
>
> "Now the environments of these colonies were very different, and they were absolutely constant. At all stages of the tide waves broke upon its upper surface, whilst the sides were in gently moving unbroken water, and the bottom was in comparative calm. * * *"

A careful study of the specimens shows that there is in all of them a tendency toward diffuse branching, but in the uppermost specimen the branches are reduced to swollen verrucæ scattered over the surface; in the next set of three there are slender branches around the periphery near the base. The calicular characters are similar in all. The septa and columella are rudimentary or obsolete, except on spreading basal expansions, where they may be distinct. This lot of specimens is very similar to *P. cespitosa* Dana.[2] The suite of specimens of the latter which I described from the Hawaiian Islands shows similar and perhaps even greater variation.

Distribution.—Indian Ocean; Amboina; Fiji Islands; represented in Hawaiian Islands by the closely related, if not identical, *P. cespitosa.*

Pocillopora damicornis (Pallas) Dana.

Plate 21, figure 2, specimen identified as *P. damicornis* by Dana; figures 3, 3*a*, specimen from Cocos-Keeling Islands.

1846. *Pocillopora damicornis* Dana, U. S. Expl. Exped., Zooph., p. 527, plate 49, figs. 7, 7*a*.
1907. *Pocillopora* Wood Jones, Proc. Zool. Soc. London for 1907, plate 17, fig. 3*a*.
1910. *Pocillopora* Wood Jones, Coral and Atolls, p. 90, text-fig. 25*a*; p. 91, text-fig. 26.

One of Dana's original specimens, from Singapore, is in the U. S. National Museum, No. 660. It seems that it is not the one figured, but it agrees in essentials with Dana's figures and the detail of figure 7*a* might have been taken from it. Esper's figure (Fortsetz., plate 37) presents its characters fairly well.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones has submitted 3 immature specimens and 2 pieces from mature colonies. The specimen figured by him is nearly typical of the species. He says: "The colonies are of wide distribution in the lagoon and on the barrier flats. Usual color brown; exposed parts of the zooid brown."

Distribution.—Cocos-Keeling Islands; Singapore; Fanning Island (collected by Carl Elschner).

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[1]Proc. Zool. Soc. London for 1907, pp. 535–536, pl. 28, fig. 3; Coral and Atolls, pp. 99, 100 (fig. 33, p. 99), 1910.
[2]See Vaughan, U. S. Nat. Mus. Bull. 59, plates 10–14.

Pocillopora danæ Verrill.

Plate 22, figures 1, 1*a*, specimen from Murray Island; figure 2, part of Verrill's type.

1846. *Pocillopora favosa* (pars) Dana, U. S. Expl. Exped., Zooph., p. 528, plate 50, fig. 1 (*non* Ehrenberg).
1864. *Pocillopora danæ* Verrill, Bull. Mus. Comp. Zool., vol. 1, p. 59.
1869. *Pocillopora danæ* Verrill, Proc. Essex Inst., vol. 6, p. 93.

The type of Verrill's *P. danæ* is in the U. S. National Museum, No. 696. Verrill's description in 1869 is good.

The following is a description of the Murray Island specimen:

Corallum forming bushy clumps, exceeding 18 cm. in height. Some main stems may be more or less prolate, and bear secondary, taller branches on the upper surfaces with shorter branches on the sides. All branches undergo subdivision. Cross-section of branches subterete. Diameter of branchlets below terminal bifurcation, 12.5 by 14 mm. Ends of branchlets usually compressed, one 7 by 17 mm. in diameter, excluding verrucæ; all intergradations to subterete with a diameter of only 7 mm. Distance between terminals of branchlets, measured between opposed verrucæ, 8 to 18 mm.

Verrucæ over terminals and on sides of branchlets and branches. Those on terminals usually compressed in planes transverse to plane of compression of branchlets, and somewhat swollen near the upper end. Diameters 3 by 5 mm., 4 by 6 mm., 5 by 6 mm.; height, up to 5 mm. or slightly more; distance apart, up to 5 mm. Lateral verrucæ, inclined toward end of branchlets or branches, up to 5 or 6 mm. in basal diameter, ends rounded. Low down on stems they are scattered and form low-domed protuberants up to 6 mm. in diameter.

Calice 1.5 mm. in diameter on terminals; 0.75 mm. in diameter on old portions of corallum. Intervening walls thin on and near terminals; thicker on older portions of corallum, up to 0.75 mm., 0.3 to 0.5 mm. frequent; depth about 0.5 mm. Cœnenchyma compact; surface granulate, granules usually blunt, a circle of about 16 around each calice; there may be one or two intervening rows or circles depending on distance apart of the calices. Septa represented by spines, not lamellate, usually distinct, even on verrucal summits, well developed near bases of branches; 12 the usual number, plane of symmetry distinct, composed of vertically arranged trabeculæ, projecting inward as spines from the wall. No definite columella; bottom of calice granulate.

Station, Murray Island.—South reef; outer edge of reef in a strong tidal current; almost awash at low tide, and subject to strong seas.

The Murray Island specimen differs from Verrill's type in that there are elongate main branches along the sides of which are lateral branches, and in that the verrucæ are somewhat larger and more tumid. But the calicular, including the septal, characters are identical, and the verrucæ are similar in form and arrangement. The differences, therefore, are probably of vegetative origin. There is resemblance to some of the outer fronds of *P. squarrosa* Dana, on the lower parts of which are low-domed verrucæ about 6 mm. in diameter; and also to *P. meandrina* var. *tuberosa* Verrill.[1]

Distribution.—Murray Island, Australia; Philippine Islands, without definite locality label, a specimen almost a duplicate of the one from Murray Island; Fiji Islands (Verrill's type).

Pocillopora verrucosa (Ellis and Solander) Lamarck.

Plate 23, figure 1, part of specimen so identified by Dana, No. 695, U. S. Nat. Mus.; figures 2, 2*a*, branch of a specimen from Cocos-Keeling Islands.

1846. *Pocillopora verrucosa* Dana, U. S. Expl. Exped., Zooph., p. 529, plate 50, figs. 3, 3*a*.
1860. *Pocillopora verrucosa* Milne Edwards, Hist. nat. Corall., vol. 3, p. 305.

Milne Edwards doubted Dana's identification of this species, but it seems to me that they were dealing with the same species. Two of Dana's specimens are

[1]See Vaughan, U. S. Nat. Mus. Bull. 59, pp. 99–100, 1907.

in the U. S. National Museum, Nos. 695 and 717. *Pocillopora verrucosa* has larger and taller verrucæ and thicker branches than *P. elegans*.

Dr. Wood Jones has sent "a fragment of a luxuriant colony, which when alive was colored vividly pink; the exposed portions of the zooids were brown."

Distribution.—Cocos-Keeling, Fiji Islands, general in the eastern Indian Ocean and western tropical Pacific. Represented in the Hawaiian Islands by the closely related, if not identical, *P. meandrina* Dana, the usual form of which is var. *nobilis* Verrill.

Pocillopora meandrina Dana.

1907. *Pocillopora meandrina* Vaughan, U. S. Nat. Mus. Bull. 59, p. 97, plate 14, figs. 3, 4; plate 22, figs. 1, 1*a*, 2, 2*a*; plate 23.

Mr. Elschner collected at Fanning Island a specimen which is essentially typical *Pocillopora meandrina*. The branches are wide, up to 9 cm., sinuous, and the summits are largely without verrucæ. Verrucæ, calices, and cœnenchymal ornamentation as usual in the species.

P. meandrina, as noted below, is very closely related to *P. verrucosa* and to *P. elegans*. It is highly probable that they are all variants of one species.

Distribution.—Hawaiian Islands; Fanning Island (C. Elschner).

Pocillopora elegans Dana.

Plate 23, figure 3, part of Dana's type; figures 4, 4*a*, branch of a specimen from Cocos-Keeling Islands.

1846. *Pocillopora elegans* Dana, U. S. Expl. Exped., Zooph., p. 532, plate 51, figs. 1, 1*a*.
1907. *Pocillopora* Wood Jones, Proc. Zool. Soc. London for 1907, plate 27, fig. 3*c*.
1910. *Pocillopora* Wood Jones, Coral and Atolls, p. 90, text-fig. 25*c*.

The original specimen of Dana, probably his figured type, is in the U. S. National Museum, No. 720.

Regarding the group of forms, designated species, to which this one belongs, I have said:[1]

"*P. meandrina* is extremely close to *P. verrucosa;* in calicular characters they overlap. The verrucæ of the latter are larger and more irregular in size, causing the corallum to have a very rough, even a ragged appearance. *P. damicornis*, *danæ*, *verrucosa*, *meandrina*, and *elegans* form a series so indistinctly broken that one is led to suspect that they are really continuous. It is probable that *P. brevicornis* and *P. lobifera* are a part of the same series."

Subsequent study leads me to believe that *P. damicornis*, as defined by Dana, is distinct, because of its longer and more tapering verrucæ, but *P. grandis* Dana and *P. squarrosa* Dana belong in the group. Perhaps several valid species may be retained, as I am able to identify each of the so-called species, and as *P. grandis* and *P. squarrosa* appear to have fairly distinctive characters. *P. eydouxi* Milne Edwards and Haime does not belong in this group, which is characterized by having inconspicuous or obsolete septa and columellæ. Gardiner's reference[2] of it to the synonymy of *P. grandis* is erroneous. *P. eydouxi* has conspicuous septa and a well-developed columella.

Besides the characters mentioned, *P. elegans* has relatively thin branches, 7 to 8 mm. thick just below the upper surfaces; small verrucæ, about 2 mm. in diameter at the base, and the summits of adult branches are naked.

I am identifying two of Dr. Wood Jones's specimens as *P. elegans;* one is nearly typical, the other shows the characteristic response of branching corals to surf conditions.

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[1]U. S. Nat. Mus. Bull. 59, p. 100, 1907. [2]Proc. Zool. Soc. London for 1898, p. 950.

Habitat, etc., Cocos-Keeling Islands.—The following notes of Dr. Wood Jones apply to the normal growth-form:

"One of the most common of all the varieties, found both on the barrier and in the lagoon, grows to considerable size; when large, some branches are plate-like, while others are broken up into many secondary branches. The color is brown or pink. The exposed portions of the zooids are brown."

As to a growth-form from the region of surf on the barrier, Dr. Wood Jones, who twice figured it,[1] says in his notes:

"A specimen taken from the barrier, where wave action is constant and powerful. Such specimens are common constituents of the composite rocks of the barrier. They present the maximum of stunting due to violent action of the surf; the growth of such colonies is limited to a few inches in height. The color of the colonies is brown; that of the exposed portions of the zooids brown."

Height of this specimen 51 mm., length 71 mm.; width in medium portion about 45 mm. The upper surface is beset with crowded verrucæ about 3 mm. in diameter at the base and about 2 mm. tall. Calices and cœnenchymal ornamentation typical for the species.

Distribution.—Cocos-Keeling; Fiji Islands.

Pocillopora eydouxi Milne Edwards and Haime.

Plate 24, figure 1, specimen from Murray Island; figures 2, 2*a*, branch of a specimen from Cocos-Keeling Islands.

1860. *Pocillopora eydouxi* Milne Edwards, Hist. nat. Corall., p. 306, plate F 4, figs. 1, 1*a*.
1897. *Pocillopora grandis* Gardiner, Proc. Zool. Soc. London for 1897, p. 950, plate 57, fig. 3 (non Dana).
1907. *Pocillopora* Wood Jones, Proc. Zool. Soc. London for 1907, plate 27, fig 3*b*.
1910. *Pocillopora* Wood Jones, Coral and Atolls, p. 90, text-fig. 25*b*.

The growth-form and the calicular characters of this species have been well presented by Milne Edwards and by Gardiner (by the latter under the erroneous name of *P. grandis*). Whether the branch summits do or do not bear verrucæ is not of specific importance, but usually in *P. eydouxi* there are no verrucæ on the terminals of fully developed branches. Milne Edwards and Haime's type is probably a peripheral branch. The cœnenchymal granulations consist of erect spinules; frequently those medially situated on the intercalicular cœnenchyma are tangentially compressed, while often a crown of erect, pointed spinules correspond to the outer ends of the septa. Several of the calices figured by Milne Edwards clearly show a crown of peripheral spinules. This cœnenchymal ornamentation constitutes the most important difference between *P. eydouxi* and *P. woodjonesi*, the species next to be described. *P. glomerata* Gardiner may be only the rough-water facies of *P. eydouxi*. I pointed out in my paper on the Hawaiian Madreporaria[2] that *P. eydouxi* is probably a synonym of *P. elongata* Dana.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones says:

"Inhabits only the still, deep water of the lagoon. The colony from which the fragments were taken was 2 feet high, and growing luxuriantly (east end of Pulu Tikus). The color is invariably brown, but far paler than that of similar species in the barrier pools; the exposed parts of the zooids are also brown."

Station, Murray Island.—Lithothamnion ridge, southeast reef.

Distribution.—Cocos-Keeling. Reported by Gardiner from Funafuti, outer reef; Rotuma, outer reef and 2 fathoms; Lifu, Loyalty Islands. The U. S. National Museum has a fine suite of specimens from Funafuti lagoon (*Albatross*, 1899).

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[1]Proc. Zool. Soc. London for 1907, plate 27, figure 3*c*. Coral and Atolls, 1910, p. 90, text-figure 25*c*.
[2]U. S. Nat. Mus. Bull. 59, p. 93, 1907.

Pocillopora woodjonesi, new species.

Plate 22, figure 3, view of a branch; plate 24, figure 3, calices.

The following is a description of the species:

Corallum somewhat similar in growth-form to *P. eydouxi*, "but the branches tend to be more dwarfed and to become fan-shaped instead of elongate."[1] The branches are short, more or less contorted plates. Depth of living tissue 38 to 62 mm.; width of branches, 38 to 73 mm.; thickness just below summits, 7.5 to 10 mm. The widest branch rapidly narrows toward its base; 62 mm. below summit the width is 32 mm. Summits without verrucæ. Texture relatively light.

Verrucæ well developed or obsolete on the sides of the branches. Where well developed, usual diameter at base about 3 mm.; height about the same; summits rounded; distance apart about 2.5 mm. The size ranges from mere swellings on the surface up to that stated; one large verruca has basal diameters of 4 by 5.5 mm., height 3.5 mm. In attitude they are perpendicular to the surface or inclined; in places they may be fused by their bases so as to form longitudinal series.

Calices on branch summits separated by thin walls; diameters 0.5 to 0.7 mm. On verrucæ, walls 0.25 to 0.5 mm. thick; diameter of calices, as much as 1 mm. Near base of living tissue, walls from about 0.5 mm. or somewhat less up to 1 mm. across, diameter of calices about 0.75 mm. Calicular fossa a rather deep pit.

Septa very distinct in the calices on the sides of the branches, but situated rather deep down; number, 12, subequal in size, do not reach the center, plane of symmetry indistinct. Columella a minute style, rising from a floor below the inner edges of the septa.

Cœnenchyma thin; *granulations radially compressed, often forming costal striations around the calicular edges, tops truncated, with secondary frosting.* The cœnenchymal ornamentation is strikingly different from that of *P. eydouxi.*

The longitudinal section shows an astonishingly great development of cellular tissue, 10.5 mm. thick, with only a surface membrance of compact cœnenchyma outside it. A fragment from another colony is 11 mm. thick on the base; cellular tissue, about 7.5 mm. The corallum is, therefore, much more porous and lighter than in *P. eydouxi.*

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones states: "From the deeper barrier pools, color pink or brown, more often brown; exposed parts of the zooids brown."

I have discussed in my paper on Hawaiian[2] corals most species of *Pocillopora* which have well-developed septa and columellæ and have nothing new to add. *P. woodjonesi* accords with none of the previously described species known to me. Its nearest relative seems to be *P. eydouxi.*

Family STYLOPHORIDÆ Verrill.

Genus STYLOPHORA Schweigger.

1820. *Stylophora* Schweigger, Handb. Naturg., p. 413.
1857. *Stylophora* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 133.

Type species: *Stylophora pistillata* (Esper).

Stylophora pistillata (Esper).

Plate 26, figures 1, 1*a*, specimen from Murray Island. Also plate 18, figure 40, of Dr. Mayer's article.

1906. *Stylophora pistillata* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 77, plate 36, figs. 94–98; plate 29, figs. 94*a*–98*a*.

Plate 26, figure 1, represents an excellent specimen about 20 cm. tall. The character of the branches and calices are well represented by Klunzinger's *St. digitata* (plate 7, fig. 5; plate 8, fig. 1), which von Marenzeller places in the synonymy of *St. pistillata.* Surface of corallum rough, upper corallite wall produced, lower obsolete; primary septa thick.

Dr. Mayer obtained a stunted specimen represented by plate 18, figure 40, in a shallow pool on the Lithothamnion ridge.

Stations.—Off the northwest reef of Murray Island, depth 18 fathoms; in protected, quiet water; bottom mud, with rocky patches.

[1]From notes of Dr. Wood Jones.

[2]U. S. Nat Mus. Bull. 59, pp. 93–97, 1907.

Southeast reef of Murray Island, Lithothamnion ridge, from shallow cleft pool, 1,740 feet from shore; water, 2.5 inches deep at low tide; bottom hard, rocky.

Distribution.—Red Sea; Murray Island; Fanning Island (Elschner).

This species has a very wide distribution, its known geographic range being from Red Sea to Fanning Islands. One specimen of *Stylophora*, collected by C. Elschner in Fanning Island, is essentially typical *St. pistillata*; another has wide branches of the form of Dana's *St. mordax*. As the latter specimen is not stunted, it appears to me that *St. mordax* may be a valid species, but it is very close to *St. pistillata*, differing principally in the greater width of the branches, which may be meandriform.

Stylophora mordax (Dana).

Plate 25, figures 1, *1a*, Dana's type; figures 2, *2a*, *2b*, specimen from Fanning Island.

1846. *Sideropora mordax* Dana, U. S. Expl. Exped., Zooph., p. 518, plate 49, figs. 1, *1a*, *1b*.

Remarks on this species are made in the last paragraph of the discussion of *Stylophora pistillata* and need not be repeated. Plate 25, figures 1, *1a*, are of Dana's type (No. 344, U. S. Nat. Mus.); plate 25, figures 2, *2a*, *2b*, are of a colony collected by Mr. Elschner at Fanning Island.

Distribution.—Fiji Islands (Dana); Fanning Island (Elschner).

Family OCULINIDÆ Milne Edwards and Haime.

Genus ACRHELIA Milne Edwards and Haime.

1849. *Acrhelia* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 29, p. 69.

Type species: *Acrhelia horrescens* (Dana).

Acrhelia horrescens (Dana).

Plate 18, figure 41 of Dr. Mayer's article.

1846. *Oculina horrescens* Dana, U. S. Expl. Exped., Zooph., p. 392, plate 28, figs. 1, *1a*, *1b*.
1850. *Acrhelia horrescens* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 13, p. 80.

Identification based on comparison with Dana's type, No. 5, U. S. Nat. Mus. One of the best-known Pacific Ocean corals; a description seems superfluous.

Station, Murray Island.—Southeast reef, line I, 1,000 feet from shore, water about 17 inches deep.

Distribution.—Australia; Fiji Islands.

Family EUSMILIIDÆ Verrill.

Genus EUPHYLLIA Dana.

1846. *Euphyllia* (pars) Dana, U. S. Expl. Exped., Zooph., p. 157.
1848. *Leptosmilia* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p. 467.
1851. *Euphyllia* Milne Edwards and Haime, Polyp. Terr. paléoz., p. 53.

Type species: *Caryophyllia glabrescens* Chamisso and Eysenhardt.

The determination of the type species of this genus necessitates discussing its history. Dana referred to it the following species:

Species referred to Euphyllia by Dana.

Dana's name.	Present name.
I. Euphyllia pavonina (Lesson)	Flabellum pavoninum Lesson.
anthophyllum (Ehrenberg)	anthophyllum (Ehrenberg).
rubra (Quoy and Gaimard)	rubra (Quoy and Gaimard).
spinulosa Dana	an immature coral of undetermined affinities.
II. Euphyllia glabrescens (C. and E.)	Euphyllia glabrescens (C. and E.).
gracilis Dana	Eusmila fastigiata (Pallas)?
aspera Dana	fastigiata (Pallas).
aperta Dana	fastigiata (Pallas)?
rugosa Dana	Euphyllia glabrescens (Chamisso and Eysenhardt).
turgida Dana	fimbriata (Spengler).
III. Euphyllia meandrina Dana	fimbriata (Spengler).
sinuosa Dana	
cultrifera Dana	

No present name is indicated for the last two species. It is hoped Mr. Matthai will supply information on them in his next publication.

Caryophyllia angulosa Quoy and Gaimard, which Milne Edwards and Haime designated as the type of their *Leptosmilia*, was subsequently named by them *Euphyllia gaimardi*. This seems to me the same as Dana's *Euphyllia rugosa*, which must be referred to the synonymy of *E. glabrescens* (Chamisso and Eysenhardt). Besides *E. glabrescens*, Milne Edwards and Haime refer to *Euphyllia* the following species considered by Dana: *turgida*, *rugosa*, and *meandrina* (syn. of *fimbriata* Spengler). As these species of Dana are reduced to two, *glabrescens* and *fimbriata*, one of them must be the type. As it is almost, if not quite, certain that *E. gaimardi*, the type of *Leptosmilia*, is a synonym of *E. rugosa*, which is a synonym of *E. glabrescens*, the preference seems to fall on *Caryophyllia glabrescens* Chamisso and Eysenhardt, which is therefore designated as the type.

Milne Edwards and Haime refer 8 living species to this genus, viz: *E. glabrescens* (Cham. and Eysenh.), *E. gaimardi* (M. Edw. and H.), *E. turgida* Dana, *E. rugosa* Dana, *E. striata* (M. Edw. and H.), *E.? gracilis* Dana, *E. fimbriata* (Spengler), and *E. plicata* (M. Edw. and H.). In the discussion to follow *E. gaimardi* and *E. rugosa* are referred to the synonymy of *E. glabrescens*; while *E. turgida* is referred to that of *E. fimbriata*. *E.? gracilis* Dana is scarcely beyond doubt a synonym of *E. fastigiata* (Pallas). It appears to me that *E. striata* is a young colony of *E. fimbriata*, and that *E. plicata* probably belongs to the same species, but a restudy of the types is necessary for a positive opinion.

Euphyllia glabrescens (Chamisso and Eysenhardt).

Plate 26, figure 2, Dana's type of *Euphyllia rugosa*; figures 3, 3*a*, specimen from Murray Island. Also plate 19, figure 48 of Dr. Mayer's article.

1821 *Caryophyllia glabrescens* Chamisso and Eysenhardt, Nov. act. curios nat., vol. 10, pt. 2, p. 369, plate 33, figs. 1, *a* and *b*.
1846. *Euphyllia rugosa* Dana, U. S. Expl. Exped., Zooph., p. 166, plate 6, figs. 3, 3*a*–3*c*.
1849. *Leptosmilia gaimardi* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 10, p. 268.
1857. *Euphyllia gaimardi* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 193.
1907. *Euphyllia rugosa* Bedot, Madréporaires d'Amboine, p. 157, plate 8, figs. 23–27.

Fig. 1.—Reproduction of original figure of *Caryophyllia rugosa* Chamisso and Eysenhardt.

Since the volume in which this species was first described is rare, the original figure is reproduced as text-figure 1. The exquisite delicacy and the accuracy of Chamisso's drawings (fig. 1) are in keeping with the charm of his inimitable story, "Peter Schlemihl." The following is his description:

"Dichotoma, hinc inde trichotoma. Rami crassitie digiti minimi, vel crassiores, extus glabriusculi vel obsolete striati, versus truncum glabri. Stella concava, centro profundissimo, lamellis margine integerrimis vel obsolete dentatis, alternatim maioribus.

"*Caryophylliæ fastigiatæ* proxima; differt ramis extus glabriusculis et stellae centro profundissimo. Icon ramos extremos exhibet. Animal actinioides, luteo-brunnescens, summam ramorum partem basi corporis brevis complectens, tentaculis numerosissimis apice capitatis extensilibus et contractilibus. Animali irritato tentacula pigre eriguntur, deflectuntur etc. Pigre quoque extenduntur et contrahuntur, neque omnia motu consentaneo. Os centrale nos fugit, adest autem sine dubio. Animal sensin findi et in animalia duo vel tria dividi videtur, unde trunci dichotomia et trichotomia."

Plate 26, figure 2, so well represents Dana's type of *Euphyllia rugosa* (No. 88, U. S. Nat. Mus.), that a detailed description appears unnecessary.

The U. S. National Museum contains about 60 specimens of this species from the Philippine Islands, mostly from Zamboanga. The suite shows that the prominence of the costæ near the calicular margins, a character to which Dana attached considerable importance, is not of specific value. The costæ may be prominent on some and obsolete on other branches in the same colony. It seems to me that *Euphyllia laxa* Gravier[1] is only a variant which grows in a slightly deeper water (15 meters).

The specimens (plate 26, figs. 3, 3*a*) collected by Dr. Mayer are all stunted or evidently unhealthy, but can be matched in the Philippine suite. Some costæ are usually prominent near the calicular margins. The coralla are often incrusted by *Lithothamnion* up to or almost to the calicular edges.

Stations, Murray Island.—Southeast reef, line I:

600 feet from shore; water 15 inches deep; bottom sandy.
800 feet from shore; water 11 inches deep; bottom hard, rocky.
820 feet from shore; water 10 inches deep; bottom broken coral.
1,000 feet from shore; water 17 inches deep.

Distribution.—Fiji Islands; Philippines; Amboina (Bedot, Quelch); Murray Islands; Minikoi and throughout the Maldive group (Gardiner). It has been stated that *Euphyllia laxa* Gravier from the Gulf of Tadjourah is almost certainly a synonym of this species. The distribution would therefore be from the east coast of Africa to the Fiji Islands.

Gardiner says:

"The colonies of this species may generally be found in hollows towards the inner side of the reef-flat or in protected situations where there is no sand or mud, both at Minikoi and throughout the Maldive group. Where it occurs, as to the south of Hulule, it is exceedingly abundant, but is nowhere a reef-builder. Color, dull green."[2]

The habit of this species is very similar to that of *Eusmilia fastigiata* (Pallas) in Florida and the West Indies. Both belong to closely related genera.

Euphyllia fimbriata (Spengler).

Plate 27, figures 1, 1*a*, two views of Dana's type of *Euphyllia turgida*; figure 2, Dana's type of *Euphyllia meandrina*.

1799. *Madrepora fimbriata* Spengler, Saml. Videnskab. selskabs Skrifter, 2d ser., vol. 5, pp. 607–614, plate opposite p. 614.
1846. *Euphyllia turgida* Dana, U. S. Expl. Exped., Zooph., p. 166, plate 9, figs. 9*a*, 9*b*.
1846. *Euphyllia meandrina* Dana, U. S. Expl. Exped., Zooph., p. 167, plate 6, figs. 4, 4*a*, 4*b*.
1848. *Leptosmilia ramosa* Milne Edwards and Haime, Ann, Sci. nat., 3d. ser., vol. 10, p. 268, plate 6, fig. 1.
1848. *Rhipidogyra daniana* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., vol. 10, p. 281, plate 6, fig. 6.
1857. *Euphyllia turgida* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 193.
1857. *Euphyllia fimbriata* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 195.
1886. *Euphyllia turgida* Quelch, Reef Corals, *Challenger* Reports, p. 75.
1904. *Euphyllia turgida* Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., vol. 2, p. 759.
1907. *Euphyllia fimbriata* Bedot, Madréporaires d'Amboine, p. 160, plate 9, 28–34.
1907. *Euphyllia picteti* Bedot, Madréporaires d'Amboine, p. 161, plate 10, figs. 35–38.
1907. *Euphyllia picteti* var. *flexuosa* Bedot, Madréporaires d'Amboine, p. 164, plate 10, figs. 39, 40.

[1] Ann. Inst. Océanogr., vol. 2, fasc. 3, p. 31, pl. 2, figs. 5–8, 1911.
[2] Fauna and Geogr. Maldive and Laccadive Arch., vol. 2, p. 759.

The illustrations of *Madrepora fimbriata* by Spengler, of *Euphyllia meandrina* by Dana, and of *Leptosmilia ramosa* and *Rhipidogyra daniana* by Milne Edwards and Haime are all good. The last-mentioned authors referred Dana's *E. meandrina* and their *Rhipidogyra daniana* to the synonymy of Spengler's species. Dana's type of *E. meandrina* (No. 94, U. S. Nat. Mus.) is here refigured on plate 8, figure 2. The illustrations of Bedot are superb. It therefore appears unnecessary to redescribe Dana's type.

This species is considered here because, as Quelch reported *Euphyllia turgida* from the shore, "Somerset, Cape York," it belongs to the Great Barrier Reef fauna. The following notes are based on Dana's type of *Euphyllia turgida*, which has been kindly loaned by the Academy of Natural Sciences of Philadelphia, catalogue number 1893, and plate 27, figures 1, 1*a*, illustrate it. The locality of the specimen, according to Dana, is Malacca, East Indies.

Corallum light, forming tufts, height more than 16.5 cm.; distance across, 18 cm. or more. Bases of branches, 31 by 28, and 24 by 35 mm. Branches bifurcate or trifurcate, distance between forks 3 to 6 cm., distance between series from 8.5 to 17.5 mm. Walls very thin, surface costate, costæ subequal or alternating in size; near the calicular edges they are up to 0.5 mm. tall, steep-sided and distant, about 1 mm. apart, and correspond to all septa.

Simple corallites 44 mm. long by 22 mm. wide; 2 or 3 corallites may form series up to 70 mm. long.

Septa thin, margins entire, the larger slightly exsert; 12 to 13 to 1 cm.; in 4 or 5 sizes. Fossa deep; no columella. Endotheca highly vesicular; dissepiments thin, about 1.75 mm. apart.

This specimen is the peripheral portion of a colony of *E. meandrina* Dana = *E. fimbriata.*

The validity of the identifications of *E. turgida* by Quelch and Gardiner now needs discussion. Quelch says:

"This species is very variable in the shape and size of its calices. They may be from about 2 to 8 cm. in diameter, and either circular, oval, triangular, or much elongate. The septa are very thin and numerous, and the axial cavity is rather shallow. An excellent figure is given by Milne-Edwards and Haime."

The following is Gardiner's comment:

"Three branched specimens with calices varying up to 4 cm. long by 2 cm. broad, closely agree with Ed. and H.'s description and figure, especially the section. The septa are scarcely exsert, and the corallites have a tendency to be constricted round their open ends. Locality: North Male, 28 f. and South Nilandu, 36 f."

The correctness of these identifications is scarcely to be doubted.

Bedot has published detailed descriptions and excellent figures of his *E. picteti* and *E. picteti* var. *flexuosa.* Regarding the former he says:

"*E. picteti* se distingue facilement d'*E. fimbriata:* en effet, sa cavité calicinale est plus élargie, évasée et profonde, ses côtes sont souvent plus proéminentes, le bord libre de la muraille est beaucoup plus irrégulier et enfin, la colonie est formée d'une lamelle repliée mais non ramifiée."

Concerning *E. picteti* var. *flexuosa* Bedot says:

"La disposition des septes, de la pseudocolumelle et des lames endothécales est la même que chez *E. picteti.* La paroi externe de la muraille portait des côtes qui ont disparu en grande partie par la suite de frottement et d'usure."

These specimens bear to typical *E. turgida* about the same relation that *E. rugosa* bears to typical *E. glabrescens.* It is therefore my opinion that *E. picteti* and its variety *flexuosa* are variants of typical *E. turgida,* and should therefore be placed in the synonymy of *E. fimbriata.*

Distribution.—Maldives, 28 fathoms and 36 fathoms (Gardiner); shore, Somerset, Cape York (Quelch); Malacca, East Indies, and East Indies without more specific locality (Dana); Amboina (Bedot); China Sea (Milne Edwards and Haime). This species has as yet not been reported from the east coast of Africa, nor so far east as the Fiji Islands.

Family ORBICELLIDÆ Vaughan.

Genus ORBICELLA Dana.

1846. *Orbicella* Dana, U. S. Expl. Exped., Zooph., p. 205.
1857. *Heliastræa* Milne Edwards and Haime, Hist. nat. Corall, vol. 2, p. 456.
1901. *Orbicella* Vaughan, Samml. Geol. Reichs. Mus. Leiden, ser. 2, vol. 2, p. 21.
1902. *Orbicella* Verrill, Trans. Conn. Acad. Arts and Sci., vol. 11, p. 93.

Type species: *Orbicella annularis* (Ellis and Solander).

Regarding *Orbicella annularis*, it should be said that the current identification of the small calicled *Orbicella* of the Floridian-West Indian region is correct. Professor J. Graham Kerr of the University of Glasgow has kindly sent me photographs of Ellis and Solander's type specimen, and they confirm the correctness of the use of the name.

In my paper cited in the synonymy I said regarding Dana's proposal of the name: "From his characterization and subsequent treatment of the species, it is evident that *Orbicella radiata* or *annularis* is regarded as typical." As it appears that a type species has hitherto not been designated, I so designate *Madrepora annularis* Ellis and Solander. Duerden has described the anatomy of the species in much detail.[1]

Orbicella versipora (Lamarck).

Plate 28, figure 1, specimen from Cocos-Keeling Islands.

1816. *Astrea versipora* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 264.
1857. *Plesiastræa versipora* Milne Edwards and Haime, Hist. nat. Corall, vol. 2, p. 490, plate D 7, fig. 5.
1914. *Favia versipora* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 103, plate 23, fig. 3; plate 25, figs. 5, 6, 9; plate 37, fig. 3.

The name of this species as given by Matthai and adopted here rests upon the assumption that Milne Edwards and Haime either based their description and figure on Lamarck's type or correctly identified the specimen which they described and figured, as Lamarck's description is inadequate. As the name *versipora* receives its status from Milne Edwards and Haime, perhaps their *annuligera* should be adopted.

Matthai's plate 25, figure 6 (specimen from Minikoi), well represents the specimen from Cocos-Keeling. As the specific identification of the specimen from French Somaliland which I referred to *Orbicella annuligera*[2] seems erroneous, I propose the name *Orbicella gravieri* for it.

Matthai says: "A badly cleaned fragment in the *Challenger* collection, with five or six corallites from Bermuda, referred by Quelch to *Astrea coarctata* (Duchassaing and Michelotti), comes nearest the present species." As I assumed that Quelch had correctly identified the species of *Favia* described by Duchassaing and Michelotti, I did not look up the *Challenger* specimens in London; therefore the names he applied to the Bermudian specimens of *Favia* appear in the synonymy of *Favia fragum* in my account of that species.[3] Of this we may be sure: no specimen of the same species of coral as the Pacific *Orbicella versipora* (or *O. annuligera* if that name is preferred) has ever been found in the Atlantic Ocean. Either Mr. Matthai has made an erroneous identification or the locality label is incorrect.

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[1]Nat. Acad. Sci. Mem., vol. 8, pp. 564–566, 1902.
[2]Proc. U. S. Nat. Mus., vol. 32, p. 252, plate 20, figure 3; plate 21; plate 22, figure 4.
[3]See especially Samml. Geolog. Reichs. Mus. Leiden, ser. 2, vol. 2, pp. 34–40, 1901.

Habitat, etc., Cocos-Keeling Islands.—A note by Dr. Wood Jones states: "Barrier coral, in rough, clear water; colonies not very large; color greenish or yellowish."

Distribution.—Indian Ocean, Seychelles to Cocos-Keeling; Australia; and perhaps Vanikoro (see Matthai, *op. cit.*, for distribution).

Orbicella gravieri, new name.

1907. *Orbicella annuligera* Vaughan, Proc. U. S. Nat. Mus., vol. 32, pp. 252–253, plate 20, fig. 3; plate 21; plate 22, fig. 4, (non *Astrea annuligera* Milne Edwards and Haime, 1849).
1911. *Orbicella annuligera* Gravier, Ann. L'Inst. Océanogr., vol. 2, fasc. 3, p. 57.

The description and figures which I have published should be adequate for the identification of the species.

Locality.—Djibouti, French Somaliland.

Orbicella curta Dana.

Plate 28, figures 2, 3, Dana's cotypes of *O. curta;* figures 4, 4*a*, one of Dana's cotypes of *O. coronata*; figure 5, specimen from Murray Island. Also plate 17, figure 32, of Dr. Mayer's article.

1846. *A. Orbicella curta* Dana, U. S. Expl. Exped., Zooph., p. 209, plate 10, figs. 3, 3*a*–3*c*.
1846. *A. Orbicella coronata* Dana, U. S. Expl. Exped., Zooph., p. 211, plate 10, figs. 4, 4*a*, 4*b*.
1899. *Orbicella wakayana* Gardiner, Proc. Zool. Soc. London for 1899, p. 753, plate 49, fig. 2.
1914. *Favia wakayana* (and synonymy) Matthai, Trans. Linn. Soc., 2d ser., Zool., p. 104, plate 25, fig. 4.

The identification is based on Dana's original specimens of *A. Orbicella curta* (Nos. 14 and 22, U. S. Nat. Mus.) and his cotypes of *A. Orbicella coronata* (Nos. 57, 58, U. S. Nat. Mus.). Although the two specimens of *O. curta* are originals of Dana, at least a part of his description is based on another specimen, as none of the septa in these is hollow. Matthai's description of the species is good, but applies more precisely to Dana's *coronata* than to *curta;* however, the variation on the original specimen of *coronata* shows that the greater exsertness of the margins of some of the principal septa is not of specific value. The calices of *coronata* on parts of the corallum are somewhat larger and more deformed than in *curta*, but in these characters there is overlapping. Diameter of fully grown calices in *O. curta*, 4.5 to 5.5 mm., in *O. coronata*, from 4.5 mm. up to 8 by 6 mm. in a large deformed calice. Reproduction normally by budding between the calices, but there is occasional fission.

There are in the U. S. National Museum specimens of this species from the following localities:

Fiji Islands, Dana's originals of *O. curta* (2 specimens);
Wake Island, an original specimen of *O. coronata* Dana;
Tahiti, Dana's original of *O. coronata* (1 specimen);
Tahiti, Flint Island (C. G. Abbot, collector);
Paumotus, Fakarawa (*Albatross*, 1899–1900), (11 specimens);
Paumotus, Hereheretue (*Albatross*, 1899–1900), (2 specimens);
Probably Paumotus (*Albatross*, 1899–1900), (2 specimens).

The more usual facies of the Paumotuan specimens is that of *O. coronata*, as elliptical calices are common, but the typical *O. curta* is also represented.

The single specimen obtained by Dr. Mayer at Murray Island evidently was growing under adverse conditions, as a part of the colony had been killed. The living corallites have somewhat thicker skeletal structures than is usual in the species, a kind of variation frequent in corals living in an unfavorable environment. The largest calice is nearly 6 mm. in diameter. Calices crowded, from less than 1 to about 2 mm. apart. Costæ thick, equal, with coarse, transversely compressed granulations.

Station, Murray Island.—Southeast reef, line I, Lithothamnion ridge, 1,756 feet from shore; hard, smooth, waterworn, rock bottom with shallow, crevice-like tide pools; water about 3 inches deep at low tide.

Distribution.—Torres Strait; Kermadec Islands; eastward to the Paumotus.

Genus CYPHASTREA Milne Edwards and Haime.

1848. *Cyphastrea* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p. 494.

Type species: *Astrea microphthalma* Lamarck.

Matthai has recently revised the species of this genus,[1] but as he has made no key to the species, nor has he otherwise clearly indicated their differential characters, I have found it convenient, in order to use his work, to prepare a synoptic table, which is here presented:

Synopsis of species of Cyphastrea described by Matthai.

Septa, 3d cycle incomplete.
  Ten usually meet the columella.
    Corralites not projecting or only up to 0.75 mm.; exotheca dense................ 1. *C. microphthama.*
Septa in 3 cycles.
  Twelve usually meet the columella.
    Corallites may project up to 2 mm.; secondary costæ thinner than the primary; exothecal vesicles thin.. 2. *C. serailia.*
    Corallites may project up to 1 mm.; secondary and primary septa equally thin; exothecal vesicles thicker than in 2.. 3. *C. chalcidicum.*
    Corallites not projecting; exothecal vesicles thin, blistery........................ 4. *C. suvadivæ.*
  Six septa meet the columella.
    Corallites project up to 0.75 mm.; exotheca dense.............................. 5. *C. gardineri.*

An inspection of this table shows that *C. serailia* and *C. chalcidicum* are very similar. In addition to the characters given there, Matthai says regarding the latter:

"Calices usually about 2 mm. in diameter, deeper than in the last species [*C. serailia*], clearly visible owing to comparative thinness and smoothness of septa. Septa more exsert than in *C. serailia*, * * * "

Professor Stanley Gardiner has sent to the U. S. National Museum a good specimen of *C. chalcidicum* from Goidu, Maldives, labeled by Mr. Matthai, and there are other specimens of it, as well as many specimens of *C. serailia*, in the U. S. National Museum. The corallites of *C. chalcidicum* usually project perpendicularly beyond the exotheca, and the outer ends of the primary and secondary septa terminate in relatively prominent costæ, while the costæ corresponding to the tertiary septa are small or obsolete. (See Matthai, *op. cit.*, pl. 12, fig. 3.) In *C. serailia* the tertiary costæ are usually distinct and well developed, although costæ corresponding to the primary and secondary septa are usually less prominent than in *C. chalcidicum* (see Matthai, *op. cit.*, pl. 11, figs. 2 and 4). Although intergrades between these forms may be found, the probability is in favor of their being different species.

With regard to *Cyphastrea ocellina* (Dana), which I have redescribed and figured in my paper on the Madreporaria of the Hawaiian Islands and Laysan,[2] and which Matthai doubtfully refers to the synonymy of *C. chalcidicum*, I will say that, in my opinion, it is a valid species. The calices are smaller than in *C. chalcidicum*, on projecting calices distinct costæ correspond to the tertiary septa, and the primary septa are thicker than the secondaries.

[1]Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, pp. 38–48, 1914.

[2]U. S. Nat. Mus. Bull. 59, pp. 103–104, plate 25, figures 4–5*a*, plate 26, figure 1, 1907.

Solenastrea bournoni Milne Edwards and Haime is not a synonym of *C. chalcidicum*, as is stated by Matthai; in fact, they are not even closely related. I studied the cotypes of the former while in Paris and subsequently Dr. Charles Gravier kindly sent me four photographs of them: two general views, natural size; two of the calices ×4; and one of the longitudinal section ×4. This is a West Indian species, which is closely related to *Solenastrea hyades* (Dana). Neither of these species has sharp, clear-cut costæ around the calices, and the intercorallites areas are almost without ornamentation, except that in some instances there may be low, rounded, rather flexuous costal markings. The calices of *S. bournoni* are smaller than in *S. hyades*, and in the former the inner margins of the tertiary septa are normally free, while in the latter they usually fuse to the sides of the included secondary septum. As these species do not occur in the Pacific Ocean they will not be further discussed here, but I will say I have descriptions of them in my unpublished manuscript on the fossil corals of the southeastern United States and the West Indies and that figures have already been prepared.[1]

Cyphastrea microphthalma (Lamarck).

Plate 29, figures 1, 1*a*, specimen from Cocos-Keeling Islands.

1816. *Astrea microphthalma* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 261.
1914. *Cyphastrea microphthalma* Matthai, Trans. Linn. Soc. London., 2d ser., Zool., vol. 17, p. 43, plate 7, fig. 6; plate 12, figs. 4–9; plate 13, figs. 1, 2, 7; plate 34, fig. 4.

As Matthai has described this species in detail, and as the specimens from Cocos-Keeling Islands exhibit no noteworthy peculiarities, a redescription seems unnecessary. One specimen and fragments of another are spheroidal or subhemispherical. Another fragment is from a specimen with a hillocky surface.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones states in his notes: "The species is found on the lagoon margin of barrier flats, in pools, and also in the lagoon. Usually greenish in color."

Distribution.—Red Sea; Indian Ocean; Philippine Islands.

Cyphastrea serailia (Forskål).

Plate 29, figs. 2, 2*a*, 2*b*, from Murray Island. Also plate 17, fig. 38, plate 18, fig. 39, of Dr. Mayer's article.

1914. *Cyphastrea serailia* Matthai, Trans. Linn. Soc. London., 2d ser., Zool., vol. 17, p. 39, plate 7, fig. 4; plate 11, figs. 1–9; plate 13, fig. 8; plate 38, figs. 1 and 5.

The following is a description of a specimen from Murray Island:

Corallum massive, upper surface rounded, with some undulations; up to 12 cm. long by 6.5 cm. wide, and 4 cm. or more thick.

Calices, usual diameter 1.5 mm., from 1 to 1.5 mm. deep. Wall not at all or only obscurely elevated. Distance apart 1.25 to 1.75 mm., evenly distributed over the surface.

Septa in adult calices, 12 are equal or subequal in size and extend to the columella; upper margins arched and distinctly exsert. The primaries are slightly longer than the secondaries, and may be traced farther into the columellar tangle; they are also usually slightly thicker. Interseptal loculi between primaries and secondaries about as wide as the combined thickness of a primary and secondary septum. The inner margins fall perpendicularly to the level of the columella; beset with slender dentations which incline upward and have bluntish ends. Faces with crowded, low, blunt granulations. Perforations usually near the columella. A third cycle of very rudimentary septa, which are mostly represented by costæ between the costal ends of the primaries and secondaries. All septa thickened in the rather thick thecal ring, where they are all represented by short costæ.

[1] These species are figured in U. S. Geological Survey, Professional Paper 98-T. Plate 98, figs. 1, 1*a*, 2, 2*a*, 3, represent *S. hyades* (Dana); plate 99, figs. 1, 1*a*, 1*b*, 2, 3, 3*a*; and plate 100, figs. 1, 2, 2*a*, 3, 3*a*, 3*b*, illustrate *S. bournoni* M. Edw. and H.

Columella composed of septal spines, depressed, diameter about one-third that of a calice.

The upper surface of the exotheca is granulate, the granulations indefinitely arranged or in the line of costal prolongations. They are rounded or squarish in transverse outline and are secondarily spinulose. The exotheca is comparatively dense, vesicles from 0.25 to 0.5 mm. apart.

Dissepiments thin, nearly horizontal, about 0.3 mm. apart.

Stations, Murray Island.—Southeast reef, line I:

540 feet from shore; water 12 inches deep; bottom rocky.
600 feet from shore; on base of *Euphyllia rugosa* Dana.
1,020 feet from shore; water 14 inches deep at lowest tide; bottom rocky.
1,600 feet from shore; water 10 inches deep.

Also from the inner side of a reef patch of the Great Barrier Reef, 6 miles east by north from Murray Island, incrusting the base of a specimen of *Acropora gemmifera* (Brook).

The described specimen of this coral in its growth-form, the number and arrangement of its septa, and in the size of the calices correspond to *Cyphastrea serailia* (Forskål), while its dense exotheca and the exothecal ornamentation correspond to the characters of *C. microphthalma* (Lam.). Comparison with a good suite of specimens of the former leads me to believe it a skeletal variation of that species.

Distribution.—Red Sea; Indian Ocean; Great Barrier Reef; Philippine Islands.

Genus LEPTASTREA Milne Edwards and Haime.

1848. *Leptastrea* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p. 494.
1849. *Leptastrea* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 12, p. 119.
1850. *Leptastrea* Milne Edwards and Haime, Brit. Foss. Corals, p. xl.

Type species: *Leptastrea roissyana* Milne Edwards and Haime.

Milne Edwards and Haime, when they originally described this genus, did not follow their usual practice and designate a type species. In their next publication they described and named two species: *L. roissyana* and *L. ehrenbergiana*, the former of which they had figured in the preceding volume of the "Annales des Sciences naturelles," plate 4, figures 6, 6*a*. As in their British Fossil Corals they designate *L. roissyana* as the type species, it is obligatory to adopt it as the genotype, an unfortunate course, as the type specimen of the species is abnormal, and the figures and description are not altogether satisfactory. The notes of Matthai do not shed light on the problem, for his text and his figures contradict each other. However, it seems to me that *L. roissyana* is a synonym of *Astræa* (=*Leptastrea*) *purpurea* (Dana), but it may be the same as *Leptastrea transversa* Klunzinger, as Matthai contends.

Klunzinger, in his "Korallenthiere des Rothen Meeres," pp. 44–47, recognized five species of *Leptastrea* and admirably characterized and figured them. They are *L. bottæ* (M. Edw. and H.) and *L. inæqualis* Klz. (here combined under the former name), *L. ehrenbergiana* M. Edw. and H., *L. transversa* Klz., and *L. immersa* Klz. They can all be identified with confidence.

Regarding Matthai's treatment of the genus, I will say that the statements in his text and the figures are often contradictory; for instance, he says of the columella of *L. roissyana*, in the synonymy of which he places Klunzinger's *L. transversa:* "Columella much compressed laterally, indistinct, primary and secondary septa almost meeting in the center and *forming with the two directive septa a transverse partition across the calyx.*" (Italics mine.) His plate 17, figure 4,

usually shows a papillate columella, without such a partition, while a few calices appear to show one. A lamellate columella is rather constantly present in Klunzinger's figure of *L. transversa*, but he explicitly states: "Die Columella besteht nur aus wenigen Papillen, welche zumeist verwachsen sind und eine quer durch den Kelchgrund ziehende, zwei der Septa verbindende Lamelle bilden * * *" Milne Edwards and Haime indicate a papillate columella for *L. roissyana*. Matthai says of *L. roissyana* "septa swollen in the theca," of *L. ehrenbergiana* "septa not swollen in the theca." His figure (plate 17, fig. 6,) of the latter shows septa thickened in the theca.

There are in the U. S. National Museum 58 specimens of *Leptastrea*, which I am classifying in the following species: *Leptastrea purpurea* (Dana), *L. transversa* Klz., *L. bottæ* (M. Edw. and H.), *L. immersa* Klz.

I believe Matthai is right in referring *Cyphastrea bottæ* and *Baryastrea solida* to the same species, but the name must be *Leptastrea bottæ*, notwithstanding that "the second larger example referred by Milne Edwards and Haime to the same species is a true *Cyphastrea* (most probably *C. serailia*)," for their figured specimen must be taken as the type, and Klunzinger in 1879 eliminated the *Cyphastrea* from the species, should there have been confusion of forms. The name *bottæ* antedates *solida* by a month, as is shown in the synonymy on page 94. I doubt Milne Edwards and Haime having used the specimen of *Cyphastrea* as a cotype, because they query the reference of *bottæ* to *Cyphastrea*, and in their description state: "Cloisons un peu débordantes, inégales, peu serrées, *comme tronquées en haut*."[1] They especially noted the truncate upper margins of the septa, one of the striking characters of the particular variant of the species represented by typical *L. bottæ*, and one which in my experience does not occur in *Cyphastrea serailia*. I agree with Matthai that *Leptastrea inæqualis* Klz. is a variant of *L. bottæ*, as the suite of specimens in the U. S. National Museum shows that they intergrade.

SYNOPSIS OF CHARACTERS OF SPECIES OF LEPTASTREA.

Before considering in detail the four species here recognized, their more salient differential characters will be indicated.

Two of the species, *L. purpurea* and *L. transversa*, have conspicuously polygonal corallites and calices (which are often deformed) and no free corallite limbs. In the former the grouping of the higher cycles of septa around the lower is usually obvious. The septal edges are conspicuously dentate, the septal faces show distinct granulations, and the columella is papillate. In the latter, septal grouping is rare, the septal edges are entire or only with microscopically fine dentations, the septal faces are nearly smooth, and the columella is either without distinct papillæ or they are only slightly developed. Usually there is a lamella extending lengthwise of the calice between the directive septa, while the principal septa outside the directive plane fuse to its sides.

The other two species have subcircular corallites and except in typical *L. bottæ* they have free corallite limbs. The septa of *L. bottæ* are dentate, although the dentations may be very fine; the septal faces are beset with distinct granulations; and there is a papillate columella. *L. immersa* has septa with subentire margins, almost smooth faces; the inner edge of the principal septa fuse loosely in the bottom of the calice; and there are few or no papillæ on the upper surface of the columella. In its smooth septal surfaces *L. immersa* bears to *L. bottæ* a relation similar to that which *L. transversa* bears to *L. purpurea*.

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[1]Not italicized in the original.

Leptastrea purpurea (Dana).

Plate 30, figures 1, 1a, Dana's type of *Astræa purpurea*; figure 2, specimen from Murray Island; figures 3, 3a, specimen from Cocos-Keeling Islands. Also plate 17, figure 33, of Dr. Mayer's article.

1846. *Astræa purpurea* Dana, U. S. Expl. Exped., Zooph., p. 239, plate 12, figs. 10, 10a–10c.
1846. *Astræa pulchra* Dana, U. S. Expl. Exped., Zooph., p. 240, plate 12, figs. 11, 11a–11f.
1849. *Leptastrea ehrenbergiana* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 12, p. 120.
1857. *Leptastræa ehrenbergana* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 494, plate D 7, fig. 4.
1857. *Prionastræa purpurea* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 524.
1867. *Leptastræa stellulata* Verrill, Proc. Essex Inst., vol. 5, p. 36.
1872. *Leptastræa purpurea* Verrill, in Dana's Corals and Coral Islands, p. 381.
1907. *Favia hawaiiensis* Vaughan, U. S. Nat. Mus. Bull. 59, p. 105, plate 26, figs. 3, 3a.
1914. *Leptastrea ehrenbergana* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 68, plate 17, figs. 5-7; plate 18, figs. 2 and 7; plate 19, figs. 3 and 4; plate 34, fig. 8

The following description is based on Dana's type of *Astræa purpurea*, which is preserved in the U. S. National Museum, No. 75:

Corallum massive, upper surface with both curved and flattish areas, transverse profile in most directions an undulating line. Greatest diameter of specimen 85 mm.; thickness, 38 mm.

Calices polygonal, separated by a narrow intercorallite groove at which the outer ends of the septa terminate. Range in diameter from 2 mm. to 9 mm., the large calices, which are usually deformed, being most commonly on the tops of undulations; 4.5 to 5 mm. is a common diameter for fully developed calices. Depth of medium-sized calices about 2 mm.; of the large calices, usually 3 mm.

The walls, including the thecal thickenings of the septa, range from 0.5 mm. to a little more than 1 mm. in thickness. The outer septal ends form subequal costæ, are swollen in the theca, and frequently are hollow. In the calices, described below, in which there are 64 septa, 8 septa are hollow in or near the theca. This condition is probably pathologic. The septal margins over the theca may be exsert up to 0.75 mm., but are usually less.

The septa vary in number according to the size of the calices. A small calice, 2 mm. in diameter, has 26 septa, alternately larger and smaller, 12 of the larger reaching the columella tangle. The 6 primary septa may be distinguished, but are scarcely more prominent than the secondary; the tertiaries even in the small calices show tendency toward fusion to the sides of the secondaries. In one half system the tertiaries have fused to the neighboring secondary and two distinct but small quaternary septa are present. A medium-sized calice, 5 mm. in diameter, has 36 septa, alternately larger and smaller. The primaries and secondaries in this calice are scarcely distinguishable and reach the columella tangle; the tertiaries usually fuse to the sides of the secondaries about half-way between the wall and columella where no quaternaries are present, but near the columella where quaternaries are present; the quaternaries have free inner edges or are fused to the sides of the included tertiaries. A large calice, 8 by 9 mm. in diameter, has 64 septa. The 6 primaries are somewhat wider and thicker than the secondaries, and are therefore distinguishable from the latter. Both of these cycles and occasionally a tertiary reach the columella. The number of septa indicates 4 complete cycles and 16 quinaries. The members of the cycles above the secondaries group around the secondaries in each system, the tertiaries fusing to the sides of the secondaries near the columella, the quaternaries fusing to the tertiaries, and quinaries fusing to the quaternaries, unless decidedly small.

The calicular fossæ are usually open, rather hopper-shaped, since, except a curve of the larger septa near the wall, the septal margins slope to near the columella—*the inner edges of the larger septa are not subvertical but slope downward and inward. The upper margins of the septa over the theca are obscurely dentate, subentire, but the presence of divergent trabeculæ may be recognized. As the columella is approached the dentations become more pronounced, so that just above the columella there is a crown of inwardly projecting, upward slanting, rather long, slender teeth, usually on all the long septa, but sometimes lobes composed of fused teeth may be present on some of the primaries. The septal faces are beset with relatively coarse, conical granulations.*

The columella is rather weakly developed; it is really a columella tangle, composed of septal spines and fused septal ends. Its diameter is about one-fifth that of the calice.

Both thickish and thin endothecal dissepiments are present; there are stout exothecal cross-connections between the walls of adjacent corallites.

Asexual reproduction by interstitial budding.

The type of species is from the Fiji Islands.

Professor Stanley Gardiner has sent to the U. S. National Museum a specimen from Turadu, Maldives, labeled *Leptastrea ehrenbergana* by Mr. Matthai. This is the same as Dana's *Astræa purpurea.*

As it seems to me probable that *L. roissyana* of Milne Edwards and Haime is a synonym of this species, their description is quoted:[1]

"Polypier encroutant et dont la forme est determinée par celle des corps qui le recouvre. Polypiérites ordinariement très-courts. Calices presque toujours très-rapprochés, circulaires, plus ou moins déformés. Columelle assez bien développée. 3 cycles cloisonnaires complets; en outre, on voit, dans une des moitiés de certains systèmes la cloison tertiaire se developper davantage et des cloisons d'un 4e cycle apparaître. *Cloisons* inégales, très-minces, débordantes, *très-granulées, à bord subentier en haut, finement dentelé près de la columelle.* Loges profondes, traverses simples, presque horizontales, distantes entre elle d'un millimètre. Diamètre des calices, de 5 à 6 millimètres."

A part of the description quoted is italicized here, so as to emphasize certain characters and facilitate comparison with the foregoing description of the type of *L. purpurea.* The figure of *L. roissyana,* given by Milne Edwards and Haime,[2] shows that the septa have sloping margins, teeth near the columella, and granulate sides, all characters of *L. purpurea.*

Regarding *L. transversa* Kls., Klunzinger says:[3]

"Sie [die Septa] sind schmal, dünn, nur leicht gekörnt, nicht oder kaumgezähnt, und nur unten finden sich an einigen Septen einige papillenartige Zähnchen, die aber auch oft fehlen. Oben debordiren sie in einen kleinen schmalen, aussen meist senkrecht abfallenden Bogen oder Lappen. Die Columella besteht nur aus wenigen Papillen, welche zumeist verwachsen sind und eine quer durch den Kelchgrund ziehende, zwei Septa verbindende Lamelle bilden, an welche sich ein theil der übrigen Septa winklig ansetzt."

Professor Stanley Gardiner has sent to the U. S. National Museum a specimen of this species which has been labeled *Leptastrea roissyana* by Mr. Matthai. The specimen is typical *L. transvera,* and at present I see no reason for referring it to *L. roissyana,* which seems to me a different species. The septal faces in the former are smooth or nearly so, and the columella is either lamellate or at least without a well-developed papillate upper surface; whereas in the latter the septal faces are granulate and the columella is papillate. Besides the specimen just noted, I am also referring to *L. transversa* a specimen obtained by C. Elschner in Fanning Island (see plate 31, figs. 1, 1*a*). Matthai may be right in combining *L. transversa* and *roissyana,* for those who have had wide experience with stony corals well know how great the range of variation is and that dogmatism on the relations of species is hazardous. It is within the range of probabilities that *L. purpurea* and *L. transversa* are variants of one species. However, until intergradation has been firmly established the different forms should be designated by different names.

There are in the U. S. National Museum 21 specimens which I am including in this species. This series exhibits three varietal facies, as follows:

(1) *Leptastrea purpurea* (Dana) typical, which is the same as the *L. ehrenbergiana* of Matthai (see note above on this page), is characterized by having the costal ends of the septa subequal and crowded, and rather sloping septal margins. (See plate 30, figs. 1, 1*a.*)

(2) This is well represented by the coral to which I applied the name *Favia hawaiiensis,* and by the small-calicled part of the colonies collected by Dr. Wood Jones in Cocos-Keeling Islands. The primary septa and in some calices some or all of the secondaries have distinctly more exsert margins than the higher cycles, and the inner margins of the principal septa are perpendicular (see plate 30, figs. 3, 3*a*); the contrast in relative exsertness of the

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[1] Hist. nat. Corall., vol. 2, p. 494.

[2] Ann. Sci. nat., 3d ser., Zool., vol. 10, plate 9, figures 6, 6*a*, 1848.

[3] Korallenth. Roth. Meer., pt. 3, pp. 46–47, 1879.

septal margins may be greater. The columella may be much compacted and form a calcareous plug. At one time I thought this variant might be discriminated as a separate species, but I am now convinced that it is only a facies of *L. purpurea.*

(3) This is represented by a specimen brought by Dr. Mayer from Murray Island. It has shallow, almost superficial, calices and the septal grouping is not so conspicuous as in typical *L. purpurea.* (See plate 30, fig. 2.) *Astræa pulchra* Dana, type No. 74, U. S. Nat. Mus., is like this variant in its septal characters, but has narrower intercorallite areas and deeper calices.

Because I found certain corallites apparently undergoing fission (*op. cit.*, fig. 3*a*) in the corals I designated as *Favia hawaiiensis*, I was misled as to their systematic affinites and did not recognize them as Verrill's *Leptastrea stellulata.* Recent comparison with a good suite of specimens of *Leptastrea* has convinced me that I committed an error and it is here corrected. Comparison of the Hawaiian specimens with specimens from the Paumotus, the Philippines, and Cocos-Keeling Islands reveals no characters whereby they can be separated from *L. purpurea.* Although the outer ends of the larger septa of the former average more exsert than in Indian Ocean specimens, to be described in the next paragraph, any discrimination in these characters breaks down by detailed comparison of the two lots, while a specimen from Port Binanga, Philippines, combined both conditions. The most important usual difference between these specimens and *L. purpurea* consists in their having 6 to 8 conspicuously large septa, with steep, nearly perpendicular inner margins and the absence or fewness of coarse septal teeth on them; while typical *L. purpurea* has 12 to 24 septa, more nearly equal in size, with sloping septal margins, and usually with coarse teeth near the columella. But the specific value of the differential characters is invalidated by another specimen from the Hawaiian Islands and an excellent specimen obtained by Mr. Elschner at Fanning Island.

The four pieces of colonies of this species in the Wood Jones collection from Cocos-Keeling Islands present most interesting variation. On one piece the range in diameter of the calices is from 3.25 mm. to 4.5 by 7 mm.; the thickness of the intercorallite walls ranges from 1 to 4 mm. (see plate 11, figs. 3, 3*a*). One of their conspicuous characters is the steepness of the inner margins of the septa which reach the columella.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones makes the following notes: "A common barrier-pool species, which incrusts the surface of rocks. While alive the colony is almost white, the zooids are brown."

As the specimen of *Leptastrea purpurea* obtained by Dr. Mayer on Murray Island is not quite typical, the following notes are made on it (plate 30, fig. 2):

Corallum massive, irregularly domed above; horizontal diameter near the base 81 by 87 mm., height 62 mm. Corallites polygonal, more or less deformed, diameters from 3 to 5 mm.; one corallite is 6 mm in diameter. Corallite walls, up to 1.25 mm. across, about 1 mm. the average. Calices rather shallow, separated by an intercorallite groove, at which the outer ends of the septa terminate. Fusion of higher to lower cycles of septa not so pronounced as is usual in the species, but fusion into groups does occur. Septal faces very granulate. Columella small, papillate. J. B. Steere obtained in the Southern Philippines a specimen similar to this. A note on the type of Dana's *Astræa pulchra* has been made in a preceding paragraph; it and the Philippine specimen are essentially identical.

Station, Murray Island.—Southeast reef flat, 1,620 to 1,670 feet from shore; water about 16 inches deep at lowest tide; hard bottom.

Distribution.—Red Sea (Klunzinger and others); Indian Ocean (Gardiner and others); Great Barrier Reef; Southern Philippines (J. B. Steere, collector); Luzon, Philippines (*Albatross*, 1908); Rotuma and Funafuti (Gardiner, Matthai); Makemo, Paumotus (*Albatross*, 1899–1900); Fanning Island (Elschner); Hawaiian Islands (as *Favia hawaiiensis* Vaughan) (W. T. Brigham).

Leptastrea transversa Klunzinger.

Plate 31, figures 1, 1*a*, specimen from Fanning Island.

1879. *Leptastræa transversa* Klunzinger, Korall. Roth. Meer., pt. 3, p. 46, plate 6, fig. 2.
1914. *Leptastrea roissyana* (pars) Matthai, Trans. Linn Soc. London, 2d ser., Zool., vol. 17, p. 67.

As *Leptastrea transversa* and *L. roissyana* have been discussed on page 92, while considering *L. purpurea*, they need only mention in this place. It is my belief that *L. roissyana* M. Edw. and H. is not the same as *L. transversa*. *Astræa pulchra* Dana resembles *L. transversa*, but differs by having obvious dentations on the margins of the higher cycles of septa and by having the last cycle of septa more developed.

Mr. Carl Elschner collected *L. transversa* at Fanning Island, and the illustrations on plate 31, figures 1, 1*a*, represent it.

Distribution.—Red Sea (Klunzinger and others); Minikoi (Gardiner, specimen in U. S. Nat. Mus.); Fanning Island (C. Elschner).

Leptastrea bottæ (Milne Edwards and Haime).

Plate 31, figures 3, 4, of specimens from Cocos-Keeling Islands.

1849. *Cyphastrea? bottæ* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 12, p. 115 [Aug. 1849].
1849. *Baryastrea solida* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 12, p. 144 [Sept. 1849].
1879. *Leptastræa bottæ* Klunzinger, Korall. Roth. Meer., pt. 3, p. 44, plate 5, fig. 9; plate 10, figs. 13*a*,13*b*.
1879 *Leptastræa inæqualis* Klunzinger, Korall. Roth. Meer., pt. 3, p. 45, plate 5, fig. 6.
1907. *Orbicella* (*Leptastrea*) *inæqualis* Vaughan, Proc. U. S. Nat. Mus., vol. 32, p. 252.
1907. *Orbicella* (*Leptastrea*) *bottæ* Vaughan, Proc. U. S. Nat. Mus., vol. 32, p. 252.
1907. *Leptastrea agassizi* Vaughan, U. S. Nat. Mus. Bull. 59, p. 101, plate 25, figs. 2, 2*a*, 3, 3*a*.
1907. *Leptastrea hawaiiensis* Vaughan, U. S. Nat. Mus. Bull. 59, p. 102, plate 25, figs. 1, 1*a*.
1914. *Leptastrea solida* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 69, plate 17, figs. 8, 9; plate 18, figs. 3–6 and 8; plate 19, figs. 5, 6.

As this species has been described in considerable detail by Matthai, another description appears unnecessary; however, the name to be applied must be considered. Matthai selected *solida* as the specific name, from *Baryastrea solida* Milne Edwards and Haime, basing his identification on their figure and description. Matthai identifies the figured type of Milne Edwards and Haime's *Cyphastrea? bottæ* with this species, but rejects the name because (apparently) they specifically confused a specimen considered by him as "most probably *C. serailia*." Of course such a misidentification in no way affects the validity of the species-name based on a figured specimen, and if *Cyphastrea? bottæ* is really this species it should be the name.[1] Matthai figures the calices of the type (*op. cit.*, plate 18, fig., 8) and makes a few notes. His figure represents typical *L. bottæ*, which was correctly identified by Klunzinger.

Matthai questionably refers *Cyphastrea oblita* Duchassaing and Michelotti to the synonymy of his *Leptastrea solida*. I have studied the specimen labeled *Cyphastrea oblita* D. and M. in the museum at Turin, have described the specimen so labeled in the museum at Paris, and Dr. Charles Gravier has sent me an excellent photograph of the latter specimen. The Turin specimen is a small-calicled variant of *Orbicella annularis*, and is the same as the *Heliastræa stellulata* of Milne Edwards and Haime, of which I have a description, written in Paris, and of which Dr. Gravier has sent me three photographs, a general view, natural size, calices ×4, and longitudinal section ×4. The Paris specimen, which seems to be the type of *Cyphastrea oblita*, is the same as *Solenastrea bournoni* M. Edw. and H., which is closely related to *Solenastrea hyades* (Dana).[2] These are common West Indian corals and are only remotely related to Pacific species.

[1]Klunzinger in 1879, as noted on p. 90 of the present paper, had eliminated the true *Cyphastrea*, should Milne Edwards and Haime really have confused forms in founding the species.

[2]See p. 88 of this memoir for discussion of these species, and U. S. Geological Survey, Professional Paper 98-T, for descriptions and illustrations.

The coral from French Somaliland, which I referred to as *Orbicella* (*Leptastrea*) *bottæ*,[1] is correctly identified, according to Klunzinger's description and figure. Klunzinger lays special stress on the character of the septal margins. He says:

"Die Septa sind ziemlich dick, besonders gegen die Mauer hin, und stark gekörnt, oben debordiren sie und sind flachbogig oder wie abgestüzt, inner fallen sie, ausser bei den flächeren Randkelchen, senkrecht ab, und es bleibt in der Mitte eine meist ziemlich enge, c. 1 Mm. von der Columella ausgefüllte Centralhöhle."

The characters of the specimens I have referred to the same species are precisely the same. Klunzinger contrasts the "obengerundeten oder etwas abgestüzten primären Septen" of *L. inæqualis* with *L. bottæ*. Remarks have already been made on Matthai's figure of the type of *L. bottæ*.

L. agassizi and *L. hawaiiensis*, which I described from the Hawaiian Islands, were discriminated as follows:

Calices 2.5 to 4.5 mm. in diameter.
  Septa in 3 cycles, a few quaternaries.
    Primaries usually decidedly exsert; primaries and secondaries reaching the columella..... *L. agassizi.*
Calices about 2 mm. rarely 3.5 mm., in diameter.
  Septa in 3 cycles.
    Primaries somewhat exsert; primaries and a few secondaries reaching the columella..... *L. hawaiiensis.*

The discrimination was largely based on the greater exsertments of the primary septa in the former. A restudy of the material has convinced me that the two forms intergrade and represent variants of one species. Comparison of the Hawaiian specimens with the material from Cocos-Keeling and Dijbouti, French Somaliland, has also convinced me that they all belong to one species, *L. bottæ* (Milne Edwards and Haime), and that another instance is furnished of a species ranging geographically from East Africa to the Hawaiian Islands.

I am referring 34 specimens in the U. S. National Museum to this species. These represent at least 4 recognizable variants, as follows:

1. *Leptastrea bottæ*, typical. Calicular rims barely or not at all projecting; upper margins of the septa truncate; paliform lobes not distinctly developed.
2. The form designated by Klunzinger as *L. inæqualis*. Corallites projecting as short cylinders or truncated cones; upper margins of septa arched; primaries notably larger than the higher cycles; calices deep, paliform lobes weakly developed; columella lax.
3. This differs from No. 2 by more nearly equal primary and secondary septa and by conspicuously developed paliform lobes on the primary and on many or all secondary septa.
4. This is the variant to which I applied the name *L. agassizi*. Calicular margins only slightly elevated. The margins of the primary septa are strikingly exsert.

Dr. Wood Jones has brought one small perfect colony and a piece of a larger one from Cocos-Keeling. The calices of each are represented by plate 31, figures 3, 4. Plate 31, figure 4, is nearly typical *L. inæqualis;* plate 31, figure 3, is near the variant numbered 3 in the foregoing account of the variations of the species.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones's notes state: "Found on the lagoon margins of barrier flats and also in the lagoon. The colonies are yellowish or greenish."

Distribution.—Red Sea; French Somaliland; Maldives; Minikoi; Cocos-Keeling Islands; at many places in the southern and central Philippines; Hawaiian Islands.

[1]Proc. U. S. Nat. Mus., vol. 32, p. 252, 1907.

Leptastrea immersa Klunzinger.

Plate 31, figures 2, *2a*, *2b*, specimen from Cocos-Keeling Islands.

1879. *Leptastræa immersa* Klunzinger, Korall. Roth. Meer., pt. 3, p. 47, plate 6, fig. 1.

The following is the original description:

"Kelche mittelmässig, ziemlich klein (3–4 Mm. breit, 4–5 Mm. lang), tief (2–3 Mm.), rundlich oder leicht polygonal, durch feine enge nicht ganz seichte lineäre Furchen getrennt und wenig (½–1 Mm.) über die letzteren erhoben, doch so dass man noch die Mauer selbst etwas vorragen sieht. Septa nicht sehr zahlreich (20–35), ungleich, die des letzten Cyklus sehr rudimemtär; meist sieht man daher nur 18–20 Septa deutlich, wovon 6–10 stärker vorspringen. Die Septa sind sehr dünn, sehr wenig gekörnt, und ganzrandig, auch unten ohne Zahn. Columella rudimentär, papillös, in der Tiefe compact. Mauern dünn. Substanz zwischen den Kelchen compact, ½–2 Mm. dick. Interseptal Plättchen 1 Mm. übereinander. Knospung extracalicinal.

Kolonie massiv, convex, bucklig. Farbe der Polypen grau. Vorkommen auf der Klippe in Klüften der Brandungszone."

Some of the septa in Klunzinger's figure show within the calices a shoulder with a concavity of the margin above it, but neither he nor Matthai describes the septal profiles of the type specimen.

The following is a description of a specimen from Cocos-Keeling:

Corallum forming incrusting masses, up to 85 by 60 mm. in diameter and 36 mm. thick, upper surface unevenly rounded, slightly undulate; texture relatively dense.

Calices subcircular, somewhat deformed by crowding, or polygonal; diameter between thecal summits, 2 to 4 mm., 3 mm. about the average for fully developed calices. Margins slightly elevated, up to 1.5 mm., often taller on the proximal than on the distal side (relative to center of corallum). Distance apart from 0.5 to 2 mm., about 1 mm. usual. Depth 2.5 mm., nearly the same as the diameter. Intercorallite depressions distinct; low, minutely granulate, subequal, or alternately wider and narrower costæ corresponding to all septa extend down the outside of the free limbs of the corallites to the bottoms of the depressions. Corallite walls thick, solid. Pits for attachment of mesenterial muscles distinct on inside of wall in interseptal loculi.

Outer ends of septa pronouncedly thickened in the walls, forming a "pseudo-theca"; inner portions thin, interseptal loculi relatively wide. First and second cycles prominently developed; the primaries and usually all the secondaries, sometimes not all but most of the secondaries, reach the columella. Margins exsert, very finely, submicroscopically dentate over the theca, with a line of trabecular divergence. Upper part of primaries narrow; below this is a slope toward the center of the calice, then a perpendicular drop to near the level of the columella, where a second widening joins the septum to other septa to form a false columella (see plate 31, fig. *2b*.) The secondary septa slope more gradually down into the calice than the primaries. The inner margins of the primaries above the shoulder are obscurely and finely dentate; below it they appear entire; the secondaries are obscurely dentate. Often winglike processes may be observed extending between the primaries and secondaries slightly above the level of the columella; these are probably incipient dissepiments. There are no pali, nor are there any septal spines in the columella area. The septal faces within the calices are sparsely beset with very small, conical granulations; the granulations more prominent on the exsert parts of the septa. The third cycle is uniformly complete, but usually less than half are distinct as thin lamallæ projecting into the calices, the others being indicated as low ridges on the tops of the walls and barely or not at all visible within the calice. Where the tertiaries are well developed, rudimentary quaternaries are present.

Columella formed by the fused inner edges of the long septa, which become somewhat compacted by stereoplasmic deposit. Papillæ usually not present on its upper surface; on one side of the corallum a few small papillæ may occasionally be seen.

Asexual reproduction by interstitial gemmation. There is one instance of fission on the corallum.

Endothecal dissepiment thickish; exotheca almost solid.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones states in his notes: "A common form; the colonies are irregular lumpy growths; color, usually some shade of yellow or pale brown."

The general aspect of the corallum of this species resembles that of *L. bottæ*, except that the corallites are more crowded and not quite so prominent, but the calicular details are very different. The primary septa of the latter have not the shoulder of the former, the septal edges are more clearly (but minutely) dentate, the septal faces more roughly granulate, usually there are paliform teeth, and there are a few papillæ on the columella. *L. immersa* is distinctly smoother. The absence of septal spines or conspicuous teeth near the columella and the absence or rarity of columellar papillæ strongly contrasts with the other species, except *L. transversa*, but the presence of obscure dentations, especially on the secondary septa near the columella, seems to indicate specific and not generic difference.

The only discrepancies between the Cocos-Keeling specimen and the one which Klunzinger described and figured seem to be that in the former a larger number of septa (8 to 12) reach the columella, the septa are thick on the corallite walls, and the walls are thick (not "dunn"). None of these characters is usually of specific value. All the other characters stated by Klunzinger are present, but he unfortunately did not describe the profile of the septal edges. His figure seems to show a profile similar to the one exhibited in the Cocos-Keeling specimen, but I can not be positive of this.

Distribution.—Red Sea; Cocos-Keeling Islands.

Genus ECHINOPORA Lamarck.

1816. *Echinopora* Lamarck, Hist. nat. Anim. sans. Vert., vol. 2, p. 252.

Type species: *Echinopora rosularia* Lamarck, which according to Matthai is a synonym of *E. lamellosa* (Esper).

Echinopora lamellosa (Esper).

Plate 32, figures 1, 1*a*, specimen from Cocos-Keeling Islands; figures 2, 2*a*, Dana's type of *E. undulata*; figure 3, Dana's type of *E. reflexa*.

1914. *Echinopora lamellosa* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 50, plate 8, fig. 6; plate 14, figs. 2–6; plate 15, fig. 1; plate 16, fig. 6.

The identification of the specimen described below is based on Matthai's description and figures and a specimen identified by him and received by the U. S. National Museum from Professor Stanley Gardiner. I have not checked the synonym he presents. *Echinopora horrida* Dana is not a synonym of this species, as suggested with a query by Matthai.

In order to present the basis for referring Dana's *E. undulata* and *E. reflexa* to the synonymy of *lamellosa*, the type of the former is illustrated by plate 32, figures 2, 2*a*; that of the latter by plate 32, figure 3.

The following is a description of a specimen of *Echinopora lamellosa* from Cocos-Keeling Islands:

The species is represented by the distal portion of a folium, 55 by 70 mm. across; growing edges thin and translucent; inner broken edge 4 to 6 mm. thick. Living calices confined to one surface, but some dead calices on the lower surface.

Diameter of larger calices about 4 mm.; distance from one row to the next 4 to 6 mm.; distance apart of calices in the same row ranges from adjoining up to 1.5 or 2 mm. Intercorallite areas longitudinally striate, with rough, stellately spinulose granulations along the striæ, about 10 striæ to 5 mm.

Septa in adult calice, 3 complete cycles, arranged as follows: the 6 primary septa are somewhat thicker and average taller than the secondaries; they decrease somewhat in thickness toward the columella, which they join. A prominent, thick, erect, spinulose granule corresponds to the thecal end of each septum, or may rarely stand back a little outside the thecal ring; within the calice is a thick, prominent, spinulose tooth, separated by a notch from the mural granule; its inner edge falls perpendicularly, sometimes recurving to

a notch just outside a rough, erect paliform tooth, which connects on its inner margin with the columella tangle. Secondary septa somewhat thinner than the primaries, decreasing in thickness toward the columella to which they fuse. Mural granules similar to those of the primaries, the septal and palar teeth similar in arrangement but less prominent and not so thick. Tertiaries usually but not always with corresponding smaller mural granules; thin within the calices, sometimes fused to the sides of the secondaries. Occasionally in a quarter system a mural granule may have no corresponding septum, as no perceptible quaternary septa are present. Septal faces coarsely and roughly granulate. Columella well developed, composed of coarse, sometimes flaky trabeculæ.

Habitat and color, Cocos-Keeling Islands.—Dr. F. Wood Jones states in his notes: "Grows as great spreading lamellæ in the deepest patches of the lagoon, where the sand flats suddenly deepen. Color while alive, rich brown."

Distribution.—Indian Ocean; Philippine Islands (a large suite in the U. S. National Museum); Fiji Islands.

Genus GALAXEA Oken.

1815. *Galaxea* Oken, Lehrb. Naturg., Th. 3, Abth. 1, p. 72.
1857. *Galaxea* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 223.

Type species: *Madrepora fascicularis* Linnæus.

Milne Edwards and Haime have reviewed the synonymy of this genus in their work cited, but did not designate a type species. However, of the species originally placed in it by Oken they retain without question *Galaxea musicalis* and *G. fascicularis*, one of which must therefore be the genotype. As *G. fascicularis* is the best-known species, I designate it as the type of the genus.

As it appears that this genus has not been reported in a fossil state, it will be mentioned that a species occurs in the "silex" bed of the upper Oligocene Tampa formation, near Tampa, Florida. This species at present, I am sorry to say, bears a *nomen nudum*, *Galaxea excelsa* Vaughan.[1] Some corrallites on one specimen project as much as 28 mm. and at the calice are 10.25 by 12 mm. in diameter. On another specimen the diameter of the corallites is 12 by 15 mm. There are somewhat more than 4 cylces of septa. I hope soon to publish an adequate description and figures of this interesting species. A second, smaller, species of *Galaxea* may be represented in the collection from Tampa, but I am not certain that the specimens are not parts of young colonies of the large species.

Galaxea fascicularis (Linnæus).

Plate 33, figure 2, Dana's type of *Anthophyllum hystrix;* figures 3, 3*a*, two views of a specimen from Murray Island; plate 34, figure 1, specimen identified by Dana as *Anthophyllum cespitosum.*

1904. *Galaxea fascicularis* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 59, plate 8, fig. 4; plate 16, fig. 4; plate 34, fig. 3; plate 38, fig 6.

The single specimen from Murray Island was not in thriving condition when collected. The following is a description of it:

Corallum begins as a small cluster, ultimately assuming a pulvinate form by extension around the edges and by upward growth in the older portion.

Corallites elliptical or deformed elliptical in transverse outline; project above perithecal surface from 4 to 5 mm. (measured to top of wall); enlarging slightly or not at all with upward growth. Diameter at calicular edge of a small nearly circular corallite 5 mm.; the range is up to 5 by 7.5 mm. The greater diameter of some corallites is 8 mm. Distance apart 1.5 to 2.5 mm. Costæ distinct at calicular edge, in two sizes according to septal cycle. Distinct or obscure lower down; edges rounded.

Septa in four complete cycles; primaries and secondaries reach and fuse to the columella; tertiaries shorter and thinner; quaternaries small and thin. Upper margins of primaries and secondaries exsert up to 2 mm. Granulations on septal faces very small and low.

[1] U. S. Nat. Mus. Bull. 90, p. 18, 1915.

Columella deep seated, formed by fusion of septal ends.

Endotheca delicate, dissepiments about 0.5 mm. apart. Peritheca composed of blister-like vesicles, 0.25 to 0.5 mm. high. Upper surface of peritheca exhibits many incomplete vesicles.

Station, Murray Island.—Southeast reef, line I, 1,600 feet from shore.

This species is positively the one designated *Anthophyllum cespitosum* by Dana and it appears to me to be the *Madrepora cæspitosa* of Esper (plate 27), which Milne Edwards and Haime place doubtfully in the synonymy of their *Galaxea laperouseana.* The latter authors, however, give only three cycles of septa for *G. laperouseana.*

Dana's original specimens of *Galaxea* in the U. S. National Museum are as follows:

G. cespitosa, No. 12, East Indies.
G. fascicularis, No. 48, Sulu Sea.
G. hystrix, No. 49, Fiji Islands.
G. clavus, No. 47, Fiji Islands.

These are all the species reported by Dana as having been collected by the U. S. Exploring Expedition. *G. hystrix* and *G. fascicularis* are undoubtedly the same species. There is a large suite of *Galaxea* of this facies in the U. S. National Museum, the specimens coming mostly from the southern Philippine Islands. The difference between *G. fascicularis* and *G. cespitosa* depends upon two characters, the relative exsertness of the septa, and whether the corallites are inverted turbinate in shape or of nearly uniform diameter from the perithecal surface to the calicular margin. In both of these characters there is so much variation that there is intergradation. But several characters hold good for the series. They are growth-form, size of normal, adult corallites, and the number and arrangement of the septa. Therefore, it is my opinion that *Anthophyllium cespitosum* Dana and probably *Madrepora cæspitosa* Esper should be added to the synonymy of *Galaxea fascicularis* (Linn.).

Distribution.—Red Sea; Indian Ocean; Great Barrier Reef; Philippine Islands; Fiji Islands. The range eastward from Fiji is not known.

Galaxea clavus (Dana).

Plate 33, figure 1, Dana's type of *Anthophyllum clavus.*

1846. *Anthophyllum clavus* Dana, U. S. Expl. Exped., Zooph., p. 403, plate 28, fig. 3, 3*a*, 3*b*.
1857. *Galaxea musicalis* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 225.
1888. *Galaxea musicalis* Quelch, Reef Corals, *Challenger* Reports, p. 71.
1914. *Galaxea musicalis* Matthai, Trans. Linn. Soc. London., 2d ser., Zool., vol. 17, p. 62, plate 16, figs 2, 3.

Quelch reports a specimen under the name *G. musicalis* from Somerset, Cape York, depth 5 fathoms. Matthai also refers the same specimen to *G. musicalis* as defined by Milne Edwards and Haime.

Dana's type of *Anthophyllum clavus*, No. 47, U. S. National Museum, is represented by plate 33, figure 1. Matthai combined *G. clavus* (Dana) and *G. musicalis*[1] as defined by Milne Edwards and Haime, a course in which I believe he is correct. The following is Milne Edwards and Haime's description[2] of the species.

"Polypiérites très écartées, libres en haut dans une certaine étendue, à côtes très-peu saillantes. Ordinairement trois cycles complets; les cloisons inégalement épaisses suivant les ordres. Périthèque très-dense, à cellules très-petites, ayant à peine un demi-millimètre dans leur plus grande étendue. Largeur des calices, 4 ou au plus 5 millim.; ils sont distants entre eux de 6 ou 7."

Although large colonies usually form ascending columns, they do not invariably do so. There is in the U. S. National Museum a colony 15.5 by 18.5 cm. in diameter at the base, which has a nodulate upper surface, but there are no columns.

[1]Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 62.
[2]Hist. nat. Corall., vol. 2, pp. 225, 226, 1857.

Regarding the name *musicalis*, which Milne Edwards and Haime applied to the species and attribute with a query to Linnæus, it is not known, and probably never will be known, what species Linnæus meant. Because of this uncertainty the name *clavus* proposed by Dana, concerning which there is no doubt, should be applied.

This species is represented in the U. S. National Museum by a suite of over 20 specimens, in addition to Dana's types. They are mostly from the southern and central Philippines.

Distribution.—Ceylon; Maldives; Torres Straits; southern and central Philippines; Fiji Islands. Not reported from the east coast of Africa or east of the Fiji Islands.

Family FAVIIDÆ Gregory.

Genus FAVIA Oken.

1815. *Favia* Oken, Lehrb. Naturg., Th. 3, Abth. 1, p. 67.
1857. *Favia* Milne Edwards and Haime, Hist. nat. Corall, vol. 2, p. 426.
1902. *Favia* Verrill, Trans. Conn. Acad. Arts and Sci., vol. 11, p. 88.

Type species: *Madrepora fragum* Esper.

Milne Edwards and Haime and Verrill have gone into the history of this generic name so extensively that further discussion is almost superfluous.

Matthai in his "Revision of the recent colonial Astræidæ possessing distinct corallites," refers to *Favia* 25 species, which I have regrouped in the following table. The numbers are those used by Matthai and indicate his order of treating the species. An asterisk means that the species is represented in the U. S. National Museum collection. Matthai's names are given in the first column, the revised names in the second column.

Calices subcircular, asexual reproduction normally by intercalicular gemmation. Genus *Orbicella.*

12.	Favia versipora (Lam.)	*	Orbicella versipora (Lam.).
13.	wakayana (Gardiner)	*	curta Dana.
14.	solidior (M. Edw. and H.) (Perhaps only a variant of *O. curta* (Dana))	*	solidior (M. Edw. and H.).

Calices elliptical, subequal fission (except in *F. pallida*). Genus *Favia.*

1.	Favia favus (Forskål)	*	Favia favus (Forskål).
4.	clouei (Valenciennes)	*	speciosa (Dana).
9.	laxa (Klunzinger)	*	laxa (Klz.).
25.	rotulosa (Ell. and Sol.)		rotulosa (Ell. and Sol.).
23.	sp? = rotumana (Gardiner)	*	rotumana (Gardiner).
21.	fragum (Esper)	*	fragum (Esper).
8.	ananas (Ell. and Sol.)		peronii (M. Edw. and H.).
11.	acropora (Linn.)	*	stelligera (Dana).
2. 3.	doreyensis M. Edw. and H. hululensis Gardiner	*	pallida (Dana)[1].
6.	bertholleti (Val.)	*	valenciennesii[2] (M. Edw. and H.)

[1]See note on p. 101, and description, pp. 105–108, for accounts of fission in this species.

[2]This species is the genotype of *Phymastrea* M. Edw. and H. I doubt the mode of junction of the corallites being of generic value, and, except discarding Valenciennes's *nomen nudum*, agree with Matthai.

Calices polygonal, solid separating walls, subequal fission, without spines on upper part of septal edges. Genus *Goniastrea.*

16. 24.	Favia hombroni (Rousseau)* sp? = tenella (Gardiner)	Probably should be referred to *Goniastrea.*

Calices polygonal, intercorallite walls fused, subequal fission, with spines on upper part of septal edges. Genus *Acanthastrea.*

19. Favia hemprichii (Ehrenberg)*	}	Probably the same species, and probably referable to *Acanthastrea.*
22. parvimurata Gardiner.		
10. hirsuta (M. Edw. and H.)		*Acanthastrea echinata (Dana).

Calices polygonal, often pentagonal, asexual reproduction by marginal fission. Genus *Favites.*

5. Favia abdita (Ell. and Sol.)	*Favites abdita (Ell. and Sol.).
18. complanata (Ehrenberg)	* complanata (Ehr.).
17. vasta (Klunzinger)	* virens (Dana).
15. halicora (Ehrenberg)	* halicora (Ehr.).
7. pentagona (Esper)	* melicerum (Ehr.).

Matthai's No. 20, *Favia favosa* (Ell. and Sol.), seems to me to be a true *Favia* and close to *F. speciosa* (Dana), notwithstanding that he says, "new corallites are formed by unequal fission." The name *favosa* is invalid for it. If it is not a synonym of a previously described species, its name will be *magnistellata* M. Edw. and H.

It will be made evident in a following description that fission in *Favia pallida* (Dana) is not really subequal, but that it is unequal. A part of the calice is cut off by a partition growing across one side or one end of the calice and rarely passing through the columellar area. The fission is not so nearly marginal as is usual in the species referred to *Favites.*

From the preceding statements it is obvious that I do not agree with Matthai in merging so many formerly recognized genera under *Favia.* I am distributing the species among the old genera, *Orbicella*, *Favia*, *Favites*, and *Acanthastrea.* It seems to me that *Phymastrea* should probably be referred to the synonymy of *Favia. Favia hombroni* (Rousseau) Matthai and *Prionastræa tenella* Gardiner (*non* Dana) appear to me more probably to belong to *Goniastrea.* The changes in the nomenclature of the species are discussed under the respective descriptions of the species. I somewhat doubt whether the coral designated *Favia hombroni* by Matthai is *Parastrea hombroni* L. Rousseau, as Rousseau's figure indicates corallites with subcircular, separate, not contiguous calices; but in the description there is the statement "ayant quelquefois leur bords soudés et subpolygonaux." Under these circumstances it seems that the name can not be made secure without a restudy of the actual type.

Favia stelligera (Dana).

Plate 34, figures 2, 2*a*, 2*b*, Dana's type of *Astræa stelligera;* plate 34, figure 3, plate 35, figures 1, 1*a*, Verrill's type of *Plesiastræa armata;* plate 35, figures 2, 2*a*, 3, specimens from Cocos-Keeling Islands; figure 4, a varietal form from Fanning Island.

1846. *A. Orbicella stelligera* Dana, U. S. Expl. Exped., Zooph., p. 216, plate 10, figs. 9*a*–9*e*.
1846. *Astræa [Fiscicella] intersepta* Dana (*non* Esper). U. S. Expl. Exped., Zooph., p. 246, plate 13, figs. 12, 12*a*–12*e*.
1857. *Favia lobata* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 434, plate D 8, fig. 3.
1872. *Plesiastræa armata* Verrill, in Dana's Corals and Coral Islands, 1st ed., p. 381.
1879. *Favia lobata* Klunzinger, Korall. Roth. Meer., pt. 2, p. 31, plate 3, fig. 9; plate 10, fig. 8.
1914. *Favia acropora* Matthai (*non* Esper), Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 102, plate 25, figs. 1, 3; plate 33, fig. 1; (plate 26, fig. 4, probably represents another species).

As Matthai applies the name *acropora* Linnæus to this species, a few remarks on its availability will be made. Gregory,[1] in his account of the corals from the elevated reefs of Barbados, applied this name to the usual small-celled West Indian species of *Orbicella*, as he considered that *annularis* Dana intergraded with it. In two of my papers[2] I followed Gregory's usage, but based my identifications on Esper's

[1]Quart. Jour. Geol. Soc. London, vol. 51, p. 272, 1895.

[2]Some fossil corals from Curaçao, Arube, and Bonaire, Samml. Geol. Reichs Mus. Leiden, ser. 2, vol. 2, pp. 23–27, 1901; Stony corals of the Porto Rican waters, U. S. Fish Com. Bull. for 1900, pp. 300–301, 1901.

figure and his statement, "Sie kommen aus den südlichen amerikanischen Meeren." Verrill attacked the usage of Gregory and myself[1], maintaining that "the name *acropora* (L.) should be discarded as indeterminable, both generically and specifically." I accepted Verrill's correction[2] with the statement: "But as Ellis and Solander had in the interval between Linnæus and Esper given a definite name to the species, I admit that it is better to use *annularis* Ell. & Sol., instead of *acropora* Linn. (Esper)."

For reasons stated the name *acropora* L. is not available for any coral.

The type of Dana's *stelligera* is in the U. S. National Museum, No. 55. As the right-hand one of Klunzinger's two figures (plate 3, fig. 9) of *Favia lobata* is so similar to Dana's type that it might almost have been made from it, a redescription of it scarcely seems necessary, but it is herewith figured.

The type of Dana's *Astræa intersepta* (*non* Esper) = *Plesiastræa armata* Verrill, is in the U. S. National Museum, No. 65. This is only a growth-form of *Favia stelligera*, with a somewhat less dense texture than is usual. The type is a segment extending probably from the center to the periphery of the corallum. It was attached by the central part of the base, it is convex on the sides, and has a flattish upper surface. Thickness, about 67 mm.; radius along line of greater diameter, about 87 mm.; radius along line of lesser diameter, about 65 mm. The size of the calices, the number and arrangement of the septa, the paliform lobes, and the columella are similar to those in the type of *F. stelligera*, but, as stated, the texture of the corallum is lighter.

Matthai's description of this species is fairly good, but there is greater range in the diameter of the calices than he indicates, as is shown by the following table:

Range in diameter of calices in Favia stelligera.

Specimen.	Range.	Specimen.	Range.
Dana's type	1 to 3.25 mm., 2 to 2.5 mm. usual.	Paumotus	2 to 3.25 mm., 2.5 usual.
Plesiastræa armata (type)	2 to 3.25 mm., 2.5 usual.	Paumotus (?), a fine specimen about 180 mm. high, rising into flat-topped, more or less gyrate lobes.	2.5 to 4 mm., 3 mm. or a little more usual.
Cocos-Keeling (1)	3 to 4 mm.		
(2)	2.5 to 3.5 mm.		
(3)	2.25 to 3.5 mm.		

The calices may be subcircular or deformed; where deformed the longer diameter rarely exceeds the larger number given in the table. There is also a wide range in variation of the thickness of the septa and costæ; they may be thick or thin and fragile on the same specimen. Asexual reproduction by subequal fission. I did not observe any instance of a partition crossing septa as in *Favites*.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones collected two variants of this species in Cocos-Keeling Islands, viz, one with thicker costæ and septa, which, he says, "occupies all stations from barrier to pools and lagoons"; and one with thinner costæ and septa, "which grows in clear water, either on the barrier or in inlets where there is not much sand." The color is "light yellow or yellow brown."

Distribution.—Red Sea; Indian Ocean; Pacific Ocean; Rotuma (Gardiner); Fiji Islands (Dana's type); Paumotus (*Albatross*, 1899–1900); Fanning Island (C. Elschner).

[1]Amer. Jour. Sci., vol. 13, p. 77, Jan. 1902.
[2]Proc. Biol. Soc. Washington, vol. 15, p. 56, 1902.

Favia stelligera var. fanningensis, new variety.

Plate 35, figure 4.

A specimen brought by Mr. Elschner from Fanning Island is very light textured, resembling *Favia laxa* (Klunzinger) in that character, and differing from the usual relatively dense skeletal texture of *F. stelligera*. Although the septal margins are somewhat more ragged, its calices are otherwise so similar to those of the latter that it apparently must be regarded as only a light-textured variant of that species. Figure 4, plate 35, which illustrates the characters mentioned, may be compared with plate 34, figures 2, 2*a*, and plate 35, figures 2 to 3, which represent the usual condition in typical examples of the species.

Locality.—Fanning Island (C. Elschner, collector).

Type: U. S. National Museum; duplicate in College of Hawaii, Honolulu.

Favia speciosa (Dana).

Plate 36, figure 1, Dana's type of *Astræa speciosa;* figures 2, 2*a*, a specimen intermediate between *A. speciosa* and *A. puteolina;* figure 3, Dana's type of *A. puteolina;* figures 4, 4*a*, plate 37, figure 1, Dana's type of *A. pandanus;* plate 37, figure 2, Dana's type of *A. fragilis;* figure 3, a specimen from Murray Island; figures 4, 4*a*, a specimen from Cocos-Keeling Islands.

1846. *Astræa speciosa* Dana, U. S. Expl. Exped., Zooph., p. 220, plate 11, figs. 1, 1*a*–1*d*.
1846. *Astræa pandanus* Dana, U. S. Expl. Exped., Zooph., p. 222, plate 11, figs. 2, 2*a*–2*d*.
1846. *Astræa puteolina* Dana, U. S. Expl. Exped., Zooph , p. 223, plate 11, figs. 3, 3*a*, 3*b*.
1846. *Astræa fragilis* Dana, U. S. Expl. Exped., Zooph., p. 230, plate 12, figs. 2, 2*a*–2*d*.
1907. *Favia okeni* Bedot, Madréporaires d'Amboine, p. 202, plate 26, figs. 130–133.
1907. *Favia pandanus* Bedot, Madréporaires d'Amboine, p. 204 plate 27, figs. 134–137.
1907. *Favia okeni* Vaughan, Proc. U. S. Nat. Mus., vol. 32, p. 256.
1914. *Favia clouei* Matthai, Trans. Linn. Soc. Lond., 2d ser., Zool., vol. 17, p. 89, plate 12, fig. 6; plate 23, figs. 1, 2, 5; plate 25, fig. 2; plate 34, fig. 1.

Valenciennes's name *clouei* is a *nomen nudum* and became valid in 1857, when Milne Edwards and Haime described the coral to which it was attached. As *Favia okeni* was described by the latter authors in the same work, although on a preceding page, the dates of the two names are the same. This species is Dana's *Astræa speciosa*, and in spite of the striking difference in appearance of the type of it and of that of *Astræa pandanus*, I believe they are variants of the same species.

Plate 36, figure 1, illustrates Dana's type of *A. speciosa*. The following is a brief description of it:

Longer diameter of calices from 9 up to 16 mm.; shorter diameter from 7 to about 11 mm. Walls around calicular apertures project nearly vertically up to 3 mm.; septal margins project about 1 mm. higher. Distance between thecal edges of adjacent corallites 2.5 to 3.5 mm. Distinct costæ, relatively thin, extend down the outside of the free limb of the corallite and meet those of adjoining corallites in the intercorallite areas; their edges regularly and rather finely dentate, the dentations tending to grade inferiorly into beading.

Septa relatively thin; up to about 18 reach the columella, with 1 or 2, occasionally 3, shorter septa between each pair of larger. Calices deep, up to 9.5 mm. Septal margins within the calice divided into two parts: an upper and outer part, which falls steeply to the level of the outer margin of the columellar fossa, has rather long, slender, and regular teeth, 6 to 9 in number; the lower part is wider than the upper, more irregularly dentate, dentations fewer and shorter, and its perpendicular inner edges surround the columellar fossa. Above the widening there is often a rather well-developed paliform lobe. Septal faces delicately granulate. Columella relatively small, composed of intertwisted septal trabeculæ.

Texture of corallum light, endothecal and exothecal dissepiments greatly developed.

Astræa puteolina Dana (see plate 36, fig. 3) differs from *A. speciosa* by having more crowded corallites and on the summit of the specimen the corrallite walls do not project as calicular rims. A raised lamellate ridge is often present in the intercorallite area where costæ from adjoining corallites meet. Near the edges, however,

the corallites have distinct, raised rims. The septal and costal characters are the same as in *A. speciosa*, and the corallum is very light.

One of the Wilkes Exploring Expedition specimens, to which no name was attached by Dana, is precisely intermediate between *A. speciosa* and *A. puteolina*. It is represented by plate 36, figures 2 and 2*a*.

Regarding *Astræa pandanus* of Dana, plate 36, figures 4, 4*a*, plate 37, figure 1, are three views of the type (No. 36, U. S. National Museum), and sufficiently illustrate the growth-form and general character of the calices. The following is a description of it:

Greater diameter of the calices ranges from 6.5 to 10 mm.; the lesser diameter from 6 to 8 mm. Margins elevated. Costæ prominent, thin, with dentate edges.

Septa thin; usually 12 to 14, sometimes 16, reach the columella; in the interseptal loculi between the longer septa there is commonly one shorter septum, sometimes there are 2 or 3 intermediate shorter septa and occasionally there is none. Margins with rather long dentations over the arch, both inside and outside the wall, and within the calice to the boundary of the columellar fossa, where the inner edges of the principal septa have a more or less developed paliform tooth and then drop perpendicularly to the periphery of the columella. Teeth faint on the vertical part of the margin.

Columella weakly developed. Exotheca and endotheca greatly developed, very vesicular.

Besides Dana's type there are in the U. S. National Museum 17 specimens collected by J. B. Steere in the southern Philippines, some of which almost duplicate the type. Among the striking characters are the light corallum and the relatively small number of septa which reach the columella. The principal difference between *A. pandanus* and *A. speciosa* consists in the larger number of septa which reach the columella in the latter. Matthai appears to have included both under one species, to which he applies the untenable name *clouei*,[1] but he is correct in considering them as belonging to one species.

Astræa fragilis Dana is another variant of the same species. It is represented by plate 37, figure 2. The calices in this are more crowded and average smaller than in *A. pandanus*, but some are 10 mm. long; width from 4 to 8 mm.

The U. S. National Museum contains a splendid suite of this species. Besides the 22 specimens discussed in the preceding remarks, there are 16 more from the Philippine Islands, 1 from Djibouti (French Somaliland), 1 from Fanning Island, collected by Mr. Carl Elschner, and 2 which will now be considered.

Dr. Mayer collected on Murray Island a single specimen (plate 37, fig. 3), which has calices up to 11.5 mm. in diameter, 11 mm. usual, and 7 to 8 mm. deep. Fission is more frequently unequal than equal. The skeletal structures are somewhat thicker than is usual in specimens from other localities, as would be expected in a shallow, near-shore specimen, and the columella is slightly larger than the usual average.

Station, Murray Island.—Southeast reef, line I, 600 feet from shore; depth of water, 15 inches; bottom, sandy.

Dr. Wood Jones has brought from Cocos-Keeling Islands a specimen (see plate 37, figs. 4, 4*a*) on which he remarks:

"This is a fragment of a boulder mass of 'floating coral.' The mass from which it was taken was a large one, at least 3 feet in diameter, which was washed up on the seaward shore of Pulu Tikus. No living coral like it was found in the atoll. Other smaller masses of floating coral were found around the atoll, generally tossed high on the beaches by the waves, all much sea-worn and rounded outwardly."

[1]*Op. cit.*, p. 89.

The corallites are 8 to 8.5 mm. in greater diameter and 6.5 to 7 mm. in lesser diameter; distance between corallite walls, 2 to 3 mm. There are 3 complete cycles of septa, and a variable number, usually only 3 or 4, of quaternary septa. About 12 septa reach the columella; the others are shorter, with free inner ends. Wall and septa thin; endothecal and exothecal dissepiments greatly developed, but thin. The texture of the corallum is very light. Columella weakly developed.

Distribution.—Red Sea; Djibouti; Maldives; Chagos; Ceylon; Cocos-Keeling Islands; Great Barrier Reef; Amboina; Philippines; Fiji Islands; Fanning Island.

Favia pallida (Dana).

Plate 38, figure 1, Dana's type of *Astræa pallida*; figures 2–7, variants from Murray Island. Also plate 16, figures 26, 27, 29, 30, of Dr. Mayer's article.

1846. *Astræa pallida* Dana, U. S. Expl. Exped., Zooph., p. 224, plate 10, figs. 13, 13*a*–13*e*.
1846. *Astræa versipora* Dana, U. S. Expl. Exped., Zooph., p. 233, plate 12, figs 5*a*, 5*b* (*non* Lamarck).
1846. *Astræa denticulata* Dana, U. S. Expl. Exped., Zooph., p. 234, plate 12, figs. 6, 6*a*–6*c*.
1872. *Astræa cellulosa* Verrill, in Dana's Corals and Coral Islands, p. 381 (*non* Duncan, 1863).
1914. *Favia doreyensis* Matthai, Trans. Linn. Soc. Lond., 2d ser., Zool., vol. 17, p. 84, plate 9, figs. 1, 3; plate 22, figs. 8, 9; plate 32, figs. 2, 3.

It is my belief that *Favia hululensis* Gardiner also is a synonym of *F. pallida*. The specimens which I am designating Facies 1 not only correspond to Matthai's[1] characterization of *F. hululensis*, but are the same as Ehrenberg's specimens of *Favia rotulosa*, three photographs of which Dr. Wilhelm Weltner sent me in 1902, two views natural size, and one view ×2. One of these views is the same as the one reproduced by Matthai on plate 35, figure 1. I also wrote a detailed description of the specimen while in Berlin in 1897, and Dr. Weltner subsequently sent me additional notes on it. Matthai says regarding *hululensis*:[1] "In general appearance this species is like a small edition of *Favia doreyensis*."

Professor Graham Kerr has sent me photographs of the type of *Madrepora rotulosa* Ellis and Solander, preserved in the Hunterian Museum, Glasgow. I have not positively identified this species. It is close to Facies 1 of *F. pallida*, but apparently distinct.

The following is a description of Dana's type of *Astræa pallida*, No. 30. U. S. National Museum, from Fiji Islands (see plate 38, fig. 1):

Corallum hemispherical, 90 mm. in diameter, 45 mm. thick.

Calices subcircular or elliptical. Diameter 9 to 11 mm. in circular calices; greater diameter of those elliptical in outline up to 11 mm. Margins on upper side elevated up to 5 mm.; on lower side may not be elevated. Depth up to 4 mm. or slightly more. Distance apart 2 to 5 mm. Intercorallite furrows between calices crossed by costæ, those of adjacent corallites usually but not always continuous.

Costæ subequal, correspond to all septa, tall and plate-like, exsert up to 1.5 mm.; sides nearly vertical; separated by interspaces up to 1 mm. wide. Rudimentary costæ, corresponding to which there are no, or only inconspicuous, septa, often alternate with the larger ones. Edges finely dentate.

In mature calices, 11 mm. in diameter, 18 septa reach the columella; there are 20 also well-developed but shorter septa, and a few very rudimentary septa corresponding to the smallest costæ. A small calice, 7.5 mm. in diameter, has 9 principal and 11 small but well-developed, and a few obscure, rudimentary septa. The outer ends somewhat thickened in the thecal ring, often forming a pseudo-theca; in places, however, where the rudimentary costæ are absent, the interseptal spaces in the thecal ring seem to have only dissepiments in them. Inner portions of septa somewhat thinner than that in the thecal rings. Edges exsert up to 1.75 mm., those of the principals slightly the more prominent. Upper margins arched, rather regularly and finely dentate; inner margins sloping or perpendicular, with several coarser dentations, the larger near the columella. Faces with small, conical granulations.

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[1] *Op. cit.*, p. 87.

Inner ends of the principal septa bear distinct, usually tall and erect, paliform teeth, which are pointed or rounded

Columella trabecular, of loose texture, diameter about one-fifth that of a calice; in a depression surrounded by the paliform teeth.

Exotheca composed of thick-walled vesicles; endotheca composed of sloping, curved dissepiments, from 0.75 to slightly more than 1 mm. apart.

Reproduction by unequal fission.

A specimen in the U. S. National Museum, No. 77, which bears the label "*Astræa cellulosa* Ver., Pacific Ocean, U. S. Expl. Exped.," appears to be a part of the original specimen of Dana's *Astræa denticulata*, which was Verrill's type. The following description is based on it:

Corallum massive; the type is a damaged specimen which evidently exceeded 10 cm. in length and 4 cm. in thickness.

Calices subcircular, elliptical, or oval in transverse outline; lesser diameter about 8 mm., greater diameter up to 10 mm., in calices not yet dividing. Depth up to 3.5 mm. Margins slightly elevated, occasionally as much as 2 mm., usually less. Distance apart from 2 to 3.5 mm. Intercorallite areas furrowed, across the bottoms of which costæ from adjacent calices in many instances are continuous.

Costæ correspond to all septa, and frequently small ones have no corresponding septa. Alternately large and small. Edges dentate, dentations compressed in plane transverse to that of septum.

Corallite walls thick; between corallites a few thick-walled exothecal vesicles.

Septa thickened in the thecal ring, thinner within calice; in a large calice, 8 by 10 mm. in diameter, 17 principals, 12 shorter but well-developed, and a number of very rudimentary septa, which are usually represented by small costæ on the thecal edge. Average 12 or 1 or 2 more principal septa. Upper margins of principals exsert up to 1 mm., arched, dentate, dentations fairly regular, others not so exsert; inner margins sloping or vertical, with rather long dentations, longest near the pali. Faces with small, conical granulations. From 6 to 11 tall, erect, stout paliform teeth, which are pointed or rounded.

Columella trabecular, poorly developed, in a depression surrounded by the pali. Diameter 1 to 1.5 mm.

Dessepiments slope slightly downward toward columella, thin, average about 1 mm. apart.

Reproduction by unequal fission.

Dana's original specimen of his *Astræa versipora* (*non* Lamarck) is No. 76, U. S. National Museum, from Singapore. It is nearly the same as *Favia pallida*, Facies 3, of the Murray Island series (see page 107, plate 38, fig. 4). The septa are highly exsert, up to 3 mm. and have roughly dentate arches. The calices are deep and the columella is weakly developed. Dana correctly observed the similarity between this specimen and his *Astræa denticulata*, which was subsequently named *Favia cellulosa* by Verrill.

The Murray Island specimens present about 6 facies, each of which is described in the following notes:

FACIES 1 (plate 38, fig. 2).

Corallum massive, rounded above, size about double that of a man's fist.

Calices subcircular or elliptical; diameter 7 to 8 mm.; distance apart 1 to 3 mm. Margins scarcely elevated, 1.5 mm. the maximum. Depth up to 4 mm.; usually less. Intercorallite furrows indistinct.

Costæ subequal, those of adjacent corallites usually but not invariably continuous; sides vertical, in places exsert up to 1.5 mm.; interspaces up to 0.75 mm. wide. In some places rudimentary costæ, with or without corresponding rudimentary septa, intercalated between the prominent costæ. Edges with rather regular dentations, which are compressed in a plane perpendicular to that of the septum.

Septa in mature calices, 16 reach the columella, 10 well-developed but shorter, and 5 or 6 very small septa, not so many rudimentary septa as rudimentary costæ. Usually 12 or a few more than 12 septa extend to the columella. The outer ends somewhat thickened

in the thecal ring. Upper edges exsert up to 1.5 mm.; dentations fairly regular. Inner margins sloping or perpendicular, with coarser dentations, the longer near the columella. Faces with small conical granulations.

Erect paliform teeth on the end of the principal septa surround the columella, which is trabecular, and about one-quarter the diameter of the calice.

Exothecal vesicles in a single row between corallites, walls thick, about 1 mm. apart; dissepiments thick, about 1 mm. apart.

Reproduction by unequal fission.

From station at Murray Island, 1,600 feet from shore, line I, southeast reef.

FACIES 2 (plate 38, fig. 3).

Facies 2 differs from Facies 1 in the following particulars:

(1) The calicular margins are more elevated, up to 3 mm.; the calices are more distant, up to 4 mm.; and the intercorallite depressions are correspondingly more distinct. (2) The principal costæ are not so tall, and the homologue of the rudimentary costæ of Facies 1 are well developed, but there are no distinct septa corresponding to those costæ.

Facies 1 and 2 are found on the same corallum from 1,600 feet from shore.

From station at Murray Island, southeast reef, line I, 1,600 feet from shore, and Lithothamnion ridge, 1,775 feet from shore.

FACIES 3 (plate 38, fig. 4; also plate 16, fig. 26, of Dr. Mayer's article.)

Facies 3 differs from Facies 2 by having (1) 7 or 8 septa thicker than the others; (2) more irregular, rougher, and more spinulose septal and costal dentations. Some of the calices of this specimen, except that they are somewhat deeper, up to 4 mm., almost duplicate those of Verrill's type of *Astræa cellulosa;* other calices closely resemble those of Dana's original specimen of *Astræa versipora* (*non* Lamarck).

From station at Murray Island, line I, southeast reef, 1,660 feet from shore, water 14 inches deep at low tide; hard, rocky bottom.

FACIES 4 (plate 38, fig. 5; also plate 16, fig. 29, of Dr. Mayer's article).

This is similar to Facies 2, except that in some calices septa of higher cycles may fuse by their inner ends to the sides of septa of a lower cycle. The fusion is usually in pairs, rarely in triplets.

From station at Murray Island, line I, southeast reef, 1,630 feet from shore; water 16 inches deep at low tide; hard bottom.

FACIES 5 (plate 38, fig. 6).

This is similar to Facies 2, except that the calices are more crowded, usually about 1.5 mm. apart.

From station at Murray Island, southeast reef, line I, Lithothamnion ridge, 1,775 feet from shore.

FACIES 6 (plate 38, fig. 7; also plate 16, figs. 27, 30, of Dr. Mayer's article.)

Facies 6 presents peculiarities so striking that it will be described in detail.

Corallum pulvinate in form, up to 13.5 cm. in diameter, 6.5 cm. thick.

Calices subcircular, oval, or subpolygonal with rounded angles. Lesser diameter from 6.5 to 9 mm.; greater up to 12 mm.; 8 by 12 mm. the size of a fully developed calice previous to division. Margins not elevated. Depth up to 5 mm. Thickness of intercorallite walls, 1 to 1.5 mm. where distant from corallum edge; up to 2 mm. near the edge.

The costæ are only the outer ends of the septa, usually not continuous between adjacent calices, the ends of the septa outside the septal arch falling steeply, almost perpendicularly, producing the appearance of a furrow between adjacent corallites. Exsert up to 1.5 mm., frequently with intermediate, low costæ.

Septa in a mature calice, 12 by 8 mm. in diameter, 14 reach the columella, 8 almost reach it; about 23 smaller, mostly rudimentary septa; in a small, subcircular calice 10 septa extend to the columella. The outer ends thickened in the thecal ring; the inner part of the larger septa strong, rather stout. Upper edges (costal ends) exsert up to 1.5 mm., arch narrow with steep sides, dentations rough, secondarily spinulose, producing a frosted

appearance, often compressed transverse to septal plane. Inner edges fall perpendicularly to the bottom of the calice; in its upper part a septum is relatively narrow, about 1.5 mm. wide. Edges dentate, dentations often with secondary granulations; rather irregular, often longer teeth near the columella. Faces with small conical granulations.

Well-developed, thickish, wide, paliform lobes on the ends of the principal septa; sides densely granulate; margins dentate.

Columella rather poorly developed, trabecular, false, of loose texture.

Exothecal vesicles thick-walled; endothecal dissepiments thin.

Reproduction by unequal fission.

Facies 6 differs from the others chiefly in the delimitation of the outer septal ends of adjacent corallites, as in all other characters it conforms to those of other specimens. In this character there is inconstancy, as in several instances costæ of adjacent corallites are continuous, while in specimens of the more usual facies of the species continuity from one calice to the next is not invariable. For these reasons, this character can scarcely be estimated as of specific value.

From stations at Murray Island, southeast reef, line I, as follows:

1,020 feet from shore, water 12 inches deep at low tide; practically no current; rocky bottom.
1,645 feet from shore; water 13 inches deep at low tide; hard, rocky bottom.
1,775 feet from shore, on Lithothamnion ridge.

Distribution of Favia pallida.—From the Maldives and Chagos eastward to Fiji Islands.

Favia danæ Verrill.

Plate 39, figures 1, 1*a*.

1846. *Astræa* [*Fiscicella*] *porcata* Dana, U. S. Expl. Exped., Zooph., p. 226, pl. 11, figs. 5, 5*a*–5*d* (*non* Esper).
1872. *Favia danæ* Verrill, in Dana's Corals and Coral Islands, p. 381.

The following is a description of Dana's original specimen (No. 32, U. S. National Museum):

Corallum massive, rounded above, 8 cm. tall, and about the same in shorter diameter.

Calices, greater diameter from 6 to 10 mm.; lesser diameter, 4 to 7.5 mm.; depth about 4 mm. Their margins are not at all raised or are only slightly tumid; the intercorallite areas are therefore flat or nearly so, width from 2.5 to 3.5 mm. Costæ thick, about as thick as or slightly thicker than the intercostal furrows, rather low; subequal, correspond to all septa. In some instances there are small costæ to which no septa correspond (similar to the condition noted in the description of *Favia pallida*, see page 105). Costal edges regularly, serrately dentate. The costæ from adjacent corallites meet in the intercostal area, usually continuous; occasionally a median ridge is developed for short distances, but is not continuous.

Septa rather thick, in two sizes, 15 to 16 longer which meet the columella, and as many shorter, in some instances 3 smaller septa between a pair of the longer. In some instances the members of the higher cycles fuse to the sides of the lower cycles, but septal grouping is only slightly developed. The inner margins fall steeply to the bottom of the fossa; they bear fairly regular, large teeth, which are from 4 to 6 in number. Usually there are no distinct paliform lobes, but they are present on some septa and then the septal margin below them is perpendicular and obscurely dentate. Septal faces with fine, conical granulations.

Columella weakly developed, rather small, about 1.5 mm. in longer diameter. Composed of more or less flaky, fused trabeculæ.

Endothecal dissepiments thin; exothecal dissepiments thick, coarse; the exotheca is almost solid.

Asexual reproduction by subequal fission.

Locality.—Tongatabu (U. S. Exploring Expedition).

There are two specimens of this species from Tongatabu, and it is not represented in the U. S. National Museum from any other locality. Of other specimens it seems most closely related to Facies 2 of *Favia pallida* (see plate 38, fig. 3), but the latter has thicker septa and much more developed, thicker, and taller pali. Asexual

reproduction in *F. pallida* is not by subequal but by very unequal fission. Therefore, so far as I may base an opinion on the material available for comparison, *Favia danæ* is a valid species.

Favia matthaii, new species.

Plate 39, figures 2, *2a*, *2b*.

The following is a description of the type of this species:

Corallum with domed upper surface; 10.5 cm. long, 8.5 mm. wide, 4 cm. thick.

Corallites rounded, subcircular, elliptical, or oval. Greater diameter from 9 to 12 mm.; lesser diameter from 7 to 9 mm. Calices rather shallow; their edges slightly raised; intercorallite areas from 2 to 5.5 mm. across. Costæ correspond to all septa, but they are low, thin, and distant, as much as 1 mm. apart, their edges dentate or beaded. Those from adjoining calices often do not meet, but disappear on the surface of the vesicular exotheca.

Septa about 36 in a fully developed calice, of which 16 meet the columella, about 12 are rudimentary, and about 8 are well developed but not long enough to reach the columella. Within the calice they are thin, but the outer ends of the larger septa are thickened in the wall, and exsert up to 1.5 mm. The exsert part is dentate according to a peculiar pattern. There is a prominent tooth over or nearly over the edge of the wall, and both inside and outside it are one or two prominent, spreading teeth. These teeth may be forked and the tips of the forks frosted. Below these larger teeth there is within the calice one or two smaller, pointed, thin, distant teeth, and still farther within the calice a circle of simple or double, wider, prominent teeth stand above the outer margin of the axial fossa. The part of the margin next the fossa slopes steeply or is perpendicular; there may or may not be dentations on it. Septal faces granulate.

Columella laxly developed, relatively small.

Endotheca and exotheca greatly developed, very vesicular.

Asexual reproduction by unequal fission; there is no instance of the division crossing the columella.

Type: No. 38391, U. S. National Museum.

Locality.—Indian Ocean, Dr. W. L. Abbott, collector. Dr. Abbott visited the Seychelles, Aldabra, Gloriosa, and Assumption Islands, all in the western Indian Ocean, but the locality label does not state from which island he obtained the corals he collected.

This species groups with *Favia pallida* (Dana), but the septa are very different, as both the descriptions and figures show.

Genus FAVITES Link.

1807. *Favites* Link, Besch. Nat. Samml., Rostock, 3d pt., p. 162.
1901. *Favites* Vaughan, Samml. Geol. Reichs Mus. Leiden, 2d. ser., vol. 2, p. 21.
1902. *Favites* Verrill, Trans. Conn. Acad. Arts and Sci., vol. 11, p. 92.

Type species: *Madrepora abdita* Ellis and Solander = *Madrepora favosa* Esper plate 45A, figure 2.

In my publication referred to in the synonymy I proposed using *Favites* Link instead of *Prionastrea* Milne Edwards and Haime, type species *Astrea abdita* (Lam.), and Verrill followed my suggestion.

Favites abdita (Ellis and Solander).

Plate 40, figure 1, Dana's type of *Astræa robusta*; figure 2, Dana's type of *A. flexuosa*; figure 3, specimen identified by Dana as *A. fusco-viridis*; figures 4, 5, specimens from Murray Island. Also plate 16, figure 31, of Dr. Mayer's article.

1846. *Astræa flexuosa* Dana, U. S. Expl. Exped., Zooph., p. 227, plate 11, figs. 6, *6a–6c*.
1846. *Astræa fusco-viridis* Dana U. S. Expl. Exped., Zooph., p. 228, plate 11, figs. 7, *7a–7c*.
1846. *Astræa robusta* Dana, U. S. Expl. Exped., Zooph., p. 248, plate 13, figs 10, *10a–10d*.
1914. *Favia abdita* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 91, plate 9, figs. 5; plate 29, figs. 1–4; plate 35, fig. 2.

Identification is based on a photograph of Ellis and Solander's type, kindly sent me by Professor J. Graham Kerr, of the University of Glasgow, Dana's original specimens, and Matthai's figures and description.

Stations, Murray Island.—Southeast reef, line I:

1,630 feet from shore; water about 15 inches deep at lowest tide: hard, rocky bottom.
1,775 feet from shore, Lithothamnion ridge.

The specimen from 1,630 feet from shore (plate 40, fig. 5) has thicker intercorallite walls and more crowded septa than those of the two specimens from the Lithothamnion ridge (plate 40, fig. 4), having more the *fusco-viridis* facies. The specimens from the Lithothamnion ridge so closely resemble *F. halicora* in some of their characters that I have vacillated between referring them to that species and to *F. abdita.* They appear to belong to the latter.

The succeeding notes are on Dana's types:

Astræa robusta Dana (type, No. 63, U. S. Nat. Mus., plate 40, fig. 1) is nearly typical *Favites abdita.* The walls between the corallites are thickened below the upper edges, which are usually acute; occasionally flat and wide, up to 3 mm., near the margin of the corallum.

Astræa flexuosa Dana (type, No. 27, U. S. Nat. Mus., plate 40, fig. 2) has large, deep calices, up to 18 by 14 mm. in diameter and 8.5 mm. deep. Intercorallites wall thick on summit, up to about 4 mm., in some instances with a sulcus on top; between a few calices near one edge of the corallum it is acute.

Astræa fusco-viridis Dana (pleisotype No. 28, U. S. Nat. Mus., plate 40, fig. 3), is similar to the type of *A. robusta*, except that the specimen is young and has not assumed a lobate growth-form.

As all these specimens are similar in having subequal outer septal ends, similar septal dentations, similar septal groupings, and similar columellar characters, they can be regarded as representing growth facies or growth stages of only one species.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones has obtained specimens of this species in Cocos-Keeling, and made the following note:

Two fragments of the same colony from a composite rock-mass in the lagoon; not at all a common coral; it appears to be far more abundant on the south side of the atoll. Color, zooid a very fine, vivid green, the coral itself yellowish.

Distribution.—Red Sea; Indian Ocean; Pacific Ocean, eastward to Fiji Islands.

Favites halicora (Ehrenberg).

Plate 41, figures 1, 2, 3, specimens from Murray Island.

1914. *Favia halicora* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 106, plate 26, figs. 3, 5–7.

Five specimens are referred to this species, and as they exhibit interesting variations they will be described in detail.

(1) Two specimens, southeast reef, line I, 1,400 feet from shore.

Specimen A (plate 41, fig. 2), growth-form initially incrusting, becoming massive, the size of a man's fist or somewhat larger. Upper surface rounded, not hillocky.

Corallites polygonal; calices polygonal, with rounded angles. Greater diameter up to 13.5 mm., average for a fully developed calice about 12 mm.; lesser diameter 10 to 12 mm. Margins not elevated. Depth about 3 mm. Thickness of intercorallite walls, 2 to 3 mm.; walls flat on top or with a very slightly raised, sharp edge. Outer ends of septa produce slightly prominent costæ which uniformly alternate in thickness. This alternation of the septa in thickness is a striking feature. Frequently costæ of adjacent calices are continuous.

Septa in a mature calice thickened in the thecal ring; 24 reach the columella; 9 are well developed, but do not extend to the columella; most of the septa of this size fuse near the columella to the side of those of lower cycles, sometimes forming a triplet. In another calice 21 reach the columella. Regularly alternating with the larger septa are small, short, thin septa. The septal margins usually slope to the columella. Margins of the larger septa coarsely dentate, 5 or 6 dentations on each inside the calicular cavities. Over the wall the

dentations are not prominent, but within the calices, just below the top of the wall, are usually one or two prominent pointed teeth, below which are shorter teeth, and near the columella are longer teeth. The last may simulate a palar crown around the columella. The septal dentation constitutes one of the peculiar features of the species. Granulations on the septal faces very small, conical.

Columella slightly depressed below the paliform teeth, well-developed, spongy, about one-third the diameter of the calicular cavity.

Reproduction by marginal fission.

Specimen B has smaller calices than A, ranging from 11 by 9 mm. down to 7.5 mm. in a mature calice; walls up to 3.5 mm. wide. In other characters the specimens are similar.

(2) One specimen, southeast reef, line I, 1,600 feet from shore (plate 41, fig. 1). This specimen has smaller calices than (1), and the walls are not so thick. Diameter of adult calices 7.5 to 9 mm.; thickness of intercorallite walls, 1.5 to 2.5 mm. Otherwise it is similar to B of (1).

(3) Two specimens (plate 41, fig. 3), 1,600 feet from shore, have calices larger, up to 12 by 15.5 mm. in diameter, and deeper, depth 7 to 8 mm., wider intercorallite areas, up to 4 or 5 mm. across; less prominent dentations on the part of the septal margins just below the upper edge of the wall; upper part of the septa narrower with steeper edges; larger septal groups formed by the fusion of the higher with lower cycles.

Some specimens of *F. halicora* have a most perplexing resemblance to some specimens of *F. abdita* (compare plate 40, fig. 4, with plate 41, fig. 2), as Matthai has pointed out. Usually the prominent septal dentations just within the calices of the former are a good discriminatory character.

Stations, Murray Island.—Southeast reef, line I, at 1,400 feet from shore; depth 9 inches; bottom hard, rocky. Also at 1,600 feet from shore; depth 10 inches.

Distribution.—Red Sea; Maldives; Murray Island; Fanning Island (Carl Elschner). This is another widely distributed Indo-Pacific species.

Favites virens (Dana).

Plate 41, figure 4, Dana's type of *Astræa virens;* figure 5, specimen from Murray Island. Also plate 16, figure 28, of Dr. Mayer's article.

1846. *Astræa virens* Dana, U. S. Expl. Exped., Zooph., p. 228, plate 11, figs. 8, 8*a*–8*d*.
1914. *Favia vasta* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 108, plate 27, figs. 3, 5, 6.

The type of *Astræa virens* Dana (No. 26, U. S. Nat. Mus., plate 41, fig. 4) is so similar to Klunzinger's figure (plate 4, fig. 2) of *Goniastræa halicora* that it might have served as the original. There are no differences to be indicated. According to Matthai this figure of Klunzinger represents "*Favia*" *vasta*. Therefore, if Matthai's synonymy is correct, the species name proposed by Dana must be accepted.

The following is a description of the Murray Island specimen:

Corallum represented by a fragment, upper surface curved, with a free edge projecting about 2 cm.

Calices up to 25 mm. long by 14 mm. wide; up to 2.5 mm. deep. Wall of adjacent corallites fused, from very thin up to 2 mm. thick.

Septa slightly thickened in the wall, rather thin within the calice; those of adjacent corallites continuous across the wall, with only slightly exsert margins, about 1 mm.; interseptal loculi open; margins sloping or with upper two-thirds narrow and almost vertical. In large calice, 25 by 14 mm. in diameter, about 30 septa reach the columella, about 12 fuse near the columella to the sides of the longer, 2 reach about half-way to the columella, and have free edges; regularly alternating with the 44 longer are as many smaller septa. Septal groups frequent, as many as 5 in a group. In smaller calices, about 25 septa reach the columella. Dentation of margins, rather regular, serrate, and smaller over the wall than within the calice; within the calice, fairly regular, 3 to 10 in number, slender or rounded on the end, somewhat increasing in prominence toward the columella. Broad paliform lobes surround the columella. Septal faces with minute, conical granulations.

Columella depressed, well-developed, composed of closely twisted trabeculæ, diameter about one-quarter that of a calice.

Reproduction by marginal fission.

Station, Murray Island.—Southeast reef, line I, 1,635 feet from shore; water 16 inches deep at lowest tide; hard, rocky bottom.

Distribution.—Red Sea; Chagos; Murray Island; Philippine Islands; Fiji Islands.

Favites pentagona (Esper).

Plate 42, figure 1, reproduction of Esper's enlarged view of the calices; figure 2, specimen from French Somaliland.

1794. *Madrepora pentagona* Esper, Pflanzenth., Fortsetz., p. 29, plate 39, figs. 1, 2.
1816. *Astrea deformis* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 264.
1848. *Aphrastrea deformis* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p. 446.
1848. *Aphrastrea deformis* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 10, p. 320, plate 9, figs. 11, 11*a*.
1849. *Aphrastrea deformis* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 11, p. 165.
1857. *Aphrastræa deformis* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 452.
1904. *Aphrastræa deformis* Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., p. 773, plate 63, fig 31.
1907. *Aphrastrea deformis* Vaughan, Proc. U. S. Nat. Mus., vol. 32, p. 255.
1914. *Aphrastrea deformis* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 122.

NON:

1914. *Favia pentagona* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 95, plate 10, fig. 5, plate 24, figs. 2–4; plate 36, fig. 4, which = *Favites melicerum* (Ehrenberg).

Plate 42, figure 1, is a reproduction of Esper's enlarged view of the calices of his *Madrepora pentagona*. Comparison with figure 1, which he says is natural size, shows the enlargement to be 2.5 times. Plate 42, figure 2, represents the calices of a specimen collected by Dr. Charles Gravier at Djibouti, French Somaliland. These calices are also enlarged 2.5 times. It is obvious that the two figures represent the same species.

Plate 42, figure 2, shows that asexual reproduction is by marginal fission, as only a small part of a corner of the parent polyp is cut off to form the new one. In this and other characters the affinity to *Favites abdita*, the genotype, is evident. Milne Edwards and Haime say regarding *Aphrastrea* in their original diagnosis: "Diffère des Goniastrée par ses murailles très-developpées et entièrement vésiculeuses." In places there is distinct theca between the distal ends of the septa, but it is interrupted, as is the theca in *Mæandra dædalea*, species of *Physogyra*, etc. The endotheca is greatly developed, very vesicular, and the corallum is light. As the interruption of the wall does not seem a character of generic value, I am referring *Aphrastrea* to *Favites* and place it near *F. abdita*.

Favia pentagona of Matthai is an entirely different species, to which Ehrenberg (according to Matthai) applied the name *Astræa melicerum*.

Distribution.—French Somaliland; Maldives; and Indian Ocean without specific localities. Not reported from the Pacific.

Favites melicerum (Ehrenberg).

Plate 41, figures 6, 6*a*, specimen from Cocos-Keeling Islands.

1834. *Astræa melicerum* Ehrenberg, Corallenth. Roth. Meer., p. 96.
1914. *Favia pentagona* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 95, plate 10, fig. 5; plate 24, figs. 2–4; plate 36, fig. 4 (non *Madrepora pentagona* Esper, 1797).

It has been shown that *Astrea deformis* Lamarck, type species of *Aphrastrea* Milne Edwards and Haime, is *Madrepora pentagona* Esper. Professor Stanley Gardiner has sent to the U. S. National Museum a specimen labeled *Favia pentagona* by Mr. Matthai. Dr. Wood Jones collected three damaged pieces of the same species in Cocos-Keeling, one of which is illustrated on plate 41, figures 6, 6*a*. As the specific name *pentagona* is inapplicable, *melicerum* Ehrenberg should be used, as it seems to be the oldest of those proposed for the species. Matthai's figures and descriptions are good.

Regarding *Favia hawaiiensis* Vaughan, which Matthai refers with a query to the synonymy of his *Favia pentagona*, I will say that I erred in placing the species in *Favia*. It is a *Leptastrea*, and is a synonym of Verrill's *L. stellulata*, which is a synonym of *L. ehrenbergiana* Milne Edwards and Haime and of *Astræa purpurea* Dana. (See page 93 for additional remarks.)

Distribution.—Red Sea; Indian Ocean from the Seychelles to Cocos-Keeling. Matthai refers one of the *Challenger* specimens from Api, New Hebrides, described by Quelch as *Goniastræa laxa*, to this species; otherwise it is not known from the Pacific Ocean.

Favites spectabilis (Verrill).

Plate 44, figures 1, 1*a*, Verrill's type of *Prionastræa spectabilis*.

1846. *Astræa magnifica* Dana, U. S. Expl. Exped., Zooph., p. 231, plate 12, figs. 3*a*–3c (*non* de Blainville).
1872. *Prionastræa spectabilis* Verrill, in Dana's Corals and Coral Islands, p. 381.

The following is a description of the type, No. 79, U. S. National Museum:

Corallum of massive growth-form, upper surface domed; horizontal diameter, 96 by 93 mm.; height, 53 mm.

Corallites separated by narrow, compact walls, which are rarely 0.5 mm. thick on the upper edge.

Calices polygonal or elongate with sinuous sides. Usual length about 1 cm.; occasionally as much as 1.5 cm.; width usually about 6 mm.; range from 4 to 8 mm. Depth about 9 mm.; it is greater than the width of the calices.

Septa crowded, about 12 to 5 mm.; alternately larger and smaller on top of the wall; upper margins scarcely exsert, the arch curved or flattish. Within the calices every second, fourth, or sixth may reach the columella. All septal margins are narrow above the crown of well-developed paliform lobes which bound the columella fossa. Septal edges regularly and finely dentate (pectinate); above the level of the paliform lobes are dentations barely visible to the naked eye; below the lobes the dentations are somewhat coarser and less regular. Septal faces finely granulate.

Columella fossa a deep pit with steep sides. Columella small, composed of laxly fused septal trabeculæ.

Asexual reproduction near the edge of the corallum is by marginal fission, but on older parts of the corallum processes extend from the sides of corallites across the cavities and form new corallites by equal or subequal fission. The illustrations (plate 44, figs. 1, 1*a*), show the latter method of division, which also occurs in *Acanthastrea echinata* (see plate 49, fig. 2).

Locality.—East Indies.

This coral has greatly puzzled me, as it combines characters of *Goniastrea* with those of *Favites*. The U. S. National Museum has 9 specimens, collected by J. B. Steere in the southern Philippines, which I am referring to the same species. The calices are not always so deep or so elongate and sinuous as in the type. The suite of specimens mentioned, although in some respects resembling *Goniastrea pectinata*, seem definitely to be *Favites*, and three of them are suggestively like *Favites abdita*. A more detailed study of the collections from the Philippine Islands might shed additional light on the limits of variation and affinities of this species, but at present I lack opportunity further to pursue the subject.

Distribution.—East Indies; southern Philippines.

Genus GONIASTREA Milne Edwards and Haime.

1848. *Goniastrea* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p. 495.

Type species: *Astrea retiformis* Lamarck.

Matthai, in his paper already cited, considers four species of *Goniastrea*, viz, *G. solida*, which he credits to Milne Edwards and Haime, although he takes the name from Forskål and gives his first reference to de Blainville, *G. retiformis* (Lam.), *G. pectinata* (Ehr.), and *G. planulata* (M. Edw. and H.). All these are represented in the U. S. National Museum. Regarding the name *solida*, which Matthai applies

to the first species of the genus as treated in his paper, the name is invalid, as it represents serial misidentification of Forskål's *Madrepora solida*, which is a species of *Porites* according to von Marenzeller. Dana applied the name *Astræa parvistella* in 1846 to the same species = *Goniastrea parvistella* (Dana) Verrill, 1872. Dana's name, therefore, is the proper one, if the species is valid. The type, from the Fiji Islands, is in the U. S. National Museum, No. 67, and is represented by plate 44, figures 2, 2*a*.

Verrill's cotypes of *Goniastrea aspera* from Loo Choo Islands are in the U. S. National Museum, Nos. 402 and 403. I should like to redescribe them in this connection, but can not do so at present. However, I will say that I doubt *G. aspera* really being *Goniastrea*. Besides having roughly and irregularly dentate septa, the intercorallite walls are often slit, making a combination of characters suggesting affinity with the *Cœloria* group of *Mæandra*.

Goniastrea parvistella (Dana).

Plate 44, figures 2, 2*a*, Dana's type of *Astræa parvistella*.

1846. *Astræa parvistella* Dana, U. S. Expl. Exped., Zooph., p. 244, plate 13, figs. 6, 6*a*–6*c*.
1914. *Goniastrea solida* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 117, plate 10, fig. 1; plate 28, figs. 3, 4; plate 31, fig. 1; plate 33, fig. 4; plate 38, fig 3.

Notes have already been made on this species.

Distribution.—Red Sea; Indian Ocean; eastward in the Pacific to the Fiji Islands, whence Dana's type came.

Goniastrea retiformis (Lam.).

Plate 15, figure 24, and plate 16, figure 25, of Dr. Mayer's article.

1816. *Astrea retiformis* Lamarck, Hist. nat. Anim. sans Vert, vol. 2, p. 265.
1914. *Goniastrea retiformis* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 119, plate 10, fig. 3; plate 31, figs. 2–5; plates 33, fig. 3; plate 38, figs. 2, 4.

Astræa cerium Dana (original specimens Nos. 64 and 69, U. S. Nat. Mus.) belongs in the synonymy of this species. No. 64 seems to be Dana's type. Probably *Astræa eximia* Dana also belongs in the same synonymy; but, although I have repeatedly searched for it, his type seems not to be in the Museum and therefore can not be discussed.

As this species is one of the best-known Pacific and Indian Ocean corals, redescription seems unnecessary.

Stations, Murray Island.—Southeast reef, line I:

500–550 feet from shore; water 6 inches deep; bottom sand and mud (plate 16, fig. 25, Dr. Mayer's article).
1,200 feet from shore, water 9 inches deep.
1,250 feet from shore, water 16 inches deep (plate 15, fig. 24, Dr. Mayer's article).
1,600 feet from shore, water 10 inches deep.

Distribution.—Red Sea; the Indian Ocean; the Great Barrier Reef; Amboina; Philippine Islands; Fiji Islands; Wake Island, etc. How far eastward it ranges from Fiji Islands is not known.

Goniastrea pectinata (Ehrenberg).

Plate 42, figures 3, 3*a*, Dana's types of *Astræa favulus*; figures 4, 4*a*, Dana's type of *Astræa favistella;* plate 43, figure 1, Dana's type of *Astræa sinuosa*; figures 2, 3, 3*a*, 4, 5, 5*a*, specimens from Murray Island. Also plate 15, figures 21, 22, 23, of Dr. Mayer's article.

1834. *Astræa pectinata* Ehrenberg, Corallenth. Roth. Meer., p. 96.
1846. *Astræa favistella* Dana, U. S. Expl. Exped., Zooph., p. 241, plate 13, figs. 2, 2*a*–2*d*.
1846. *Astræa sinuosa* Dana, U. S. Expl. Exped., Zooph., p. 243, plate 13, figs. 5, 5*a*–5*c*.
1879. *Goniastræa pectinata* Klunzinger, Korall. Roth. Meer., pt. 3, p. 34, plate 4, fig. 6.
1879. *Goniastræa favus* Klunzinger, Korall. Roth. Meer., pt. 3, p. 35, plate 4, fig. 4, plate 10, fig. 7.
1914. *Goniastrea pectinata* (pars) Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 120, (*non* plate 28, fig. 6, *nec* plate 37, fig. 1).

NON:
1907. *Goniastrea pectinata* Vaughan, Proc. U. S. Nat. Mus., vol. 32, p. 257.

Apparently there is no doubt regarding the type of this species, as Klunzinger states in the explanation of his figure "Exemplar von Ehrenberg aus dem Rothen Meere, No. 726 des Mus. Berol. (als *Astræa pectinata*)." Klunzinger says in his text: "Von den Dana'schen Arten steht *Astr. favistella* oder *sinuosa* die sehr wohl am nächsten."

Apparently I have confused the nomenclature of these corals by misidentifying specimens brought by Dr. Gravier from Djibouti, French Somaliland, referring them to *G. pectinata* instead of to *G. planulata;* and in my opinion Matthai has committed the same error in designating his plate 28, figure 6, and plate 37, figure 1, as *G. pectinata.*

Dana's type of *Astræa favistella* is illustrated by plate 42, figures 4, 4*a*, and his type of *Astræa sinuosa* by plate 43, figure 1. The type of *Astræa favulus*, which seems to belong to the same species, is represented by plate 42, figures 3, 3*a*. There is in the U. S. National Museum a fine suite of this species from the Philippine Islands.

The following is a description of the specimen represented by plate 43, figure 2, taken about 700 feet from shore on the southeast reef, Murray Island:

Corallum arched above, margins irregular; dimensions, 76 mm. long, 68 mm. wide, 40 mm. thick. Relatively heavy.

Calices polygonal in outline; width about 5 mm.; length in those undergoing fission up to 9 mm., usually less. Depth 4 to 5 mm.

Intercorallite walls sharp on the summit, except in places near the periphery; but slightly below the edge they are thickened up to 1.5 mm. Near the periphery of the corallum the thickness may somewhat exceed 2 mm.

The septal ends of adjacent calices may be opposed; usually a rudimentary septum is opposite a larger one, or they may alternate. The upper margins rise very slightly above the edge of the wall. For about 1 mm. from their outer ends the upper edges slope very slightly, they are almost horizontal, then they curve downward and the inner edges fall almost perpendicularly to the bottom of the calices. The upper septal margins have a strikingly flattened appearance, strongly contrasting with *G. retiformis*. The septal edges finely and regularly dentate. Faces with minute, usually blunt granulations. Total number of septa about 40 in a calice 5 by 6.5 mm. in diameter; of these, 14 reach the columella, 10 are shorter, and the others are rudimentary, some scarcely visible. More than 12 septa usually reach the columella, and have on their inner ends erect paliform lobes, with rounded upper margins and granulate sides. The pali resemble those of *G. retiformis*.

The columella is trabecular, occurs in a depression below the palar crown, and is about 1 mm. in diameter, slightly less than one-quarter the diameter of a calice.

This description fits Dana's type of *A. sinuosa*, except that the upper edges of the septa in the latter on the average are more sloping and some calices therefore look more open; otherwise a description of one specimen fits the other.

Dr. Mayer obtained 20 other specimens of *Goniastrea pectinata* on the Murray Island reef. The variation is simply bewildering. In order to illustrate it the following figures have been made (plate 43): figure 2, specimen on which the foregoing description is based; figures 3, 3*a*, views of calices on opposite ends of the same specimen; figure 4, calices of a third specimen; figures 5, 5*a*, views of calices on opposite ends of a fourth specimen.

The principal variation is in the character of the wall between adjacent corallites and in the depth of the calices. In general when the walls are wide the calices are shallow. The walls are widest, up to 3 mm., in young incrusting colonies and near the edges of older colonies. Usually on the summits of domed, healthy specimens the upper edge of the wall is acute, but is thickened below by curved, sloping dissepiments which occur in a zone outside more slightly curved dissepiments.

Stations, Murray Island.—Southeast reef, line I:

400 feet from shore; water 4.5 to 5 inches deep.
525 feet from shore; water 12 inches deep; sandy bottom.
600 feet from shore; water 6.5 to 10 inches deep; sandy bottom.
600 to 640 feet from shore; water 10 inches deep; bottom sandy.
675 to 720 feet from shore; water 12 inches deep; bottom sandy.
700 feet from shore; water 12 inches deep.
800 feet from shore; water 10 to 11 inches deep; bottom broken coral.
1,000 feet from shore; water 10 to 16 inches deep; bottom hard, rocky, broken coral.

Distribution.—Red Sea; Great Barrier Reef; southern Philippine Islands; Fiji Islands.

Goniastrea planulata Milne Edwards and Haime.

1849. *Goniastrea planulata* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool. vol. 12, p. 162.
1907. *Goniastrea pectinata* Vaughan, Proc. U. S. Nat. Mus., vol. 32, p. 257 (non *Astræa pectinata* Ehrenberg).
1907. *Goniastrea pectinata* (pars) Matthai, Trans. Linn. Soc. London, Zool., 2d ser., vol. 17, plate 28, fig. 6; plate 37, figure 1 (*non* Ehrenberg).
1907. *Goniastrea planulata* Matthai, Trans. Linn. Soc. London, Zool., 2d ser., vol. 17, p. 121, plate 28, fig. 5; plate 31, figs. 7, 8.

As remarked on page 115, it is evident that I wrongly identified as *G. pectinata* specimens submitted by Dr. Gravier, and it seems that Matthai has committed the same error with similar specimens.

Professor Stanley Gardiner has sent to the U. S. National Museum a specimen from Salomon Island, Chagos Group, labeled by Mr. Matthai, who has figured Milne Edwards and Haime's type in his work cited in the synonymy (plate 31, fig. 7). A comparison of the specimen transmitted by Professor Gardiner with Milne Edwards and Haime's original description and with the figures of the type published by Mr. Matthai established the correctness of its identification. This specimen incrusts dead coral of the same species and Lithothamnion, and evidently is a colony which had been largely killed and subsequently regenerated. It can be properly compared only with the incrusting lower part of such colonies as I described in my paper on corals from French Somaliland and of the marginal part of such as Matthai figures on plate 37, figure 1. There are two of the French Somaliland specimens in the U. S. National Museum, and I have made the comparison indicated, with the result that I am changing the identification of the specimens. An inspection of Matthai's figures 5 and 6, plate 28, shows that the principal difference is in the greater development of the pali and in the shallower calices of figure 5, which is referred to *G. planulata*, as compared with figure 6, which is referred to *G. pectinata*. This is the kind of variation which is common in colonies living under adverse conditions as compared with those more favorably situated, or the peripheral parts of colonies as compared with summit areas.

Distribution.—Red Sea; Djibouti (French Somaliland); Maldives; Chagos; at present known only in the Red Sea and Indian Ocean.

Goniastrea benhami Vaughan.

Under this name I have described a coral in the paper entitled "Some corals from Kermadec Islands" mentioned on page 67 of this memoir. The original description and six figures have been transmitted for publication in the Transactions of the New Zealand Institute. In order to round out the treatment of the genus *Goniastrea*, the description of the species and the comments on its affinities are also published here.

Description of holotype.—Corallum with a small basal attachment, from which it grows outward with an upwardly inclined, subhorizontal, or undulate lower surface. Epitheca distinct, thin, wrinkled, finely striate. Upper surface curved, with one small hump.

Length of radius of corallum, 9 cm. (diameter, about 18 cm.); thickness at center, 5 cm.; thickness at edge, from a mere basal membrane at the ends of valleys up to 5 mm., the height of a colline. Texture light.

Intercorallite walls thin, sometimes with slits between the septa.

Calices circumscribed or in series, but where they occur in series the calicinal centers are distinct. Circumscribed calices, about 7 by 8 mm. in diameter; the series range from 9 mm. wide and 17 mm. long to 6 mm. wide and 44 mm. long. Range in width from 6 to 9 mm.; in length from 8 to 44 mm. Depth from 5 to 6 mm. Distance from the edge of one columella to the edge of the next in the series from 2 to 5.5 mm.

Septa thin, 10 to 12 within 5 mm.; *i. e.*, 20 to 24 to 1 cm.; alternately larger and smaller with fair regularity; opposed outer septal ends meet in an angle on the colline summit (a larger usually but not invariably opposite a smaller). Below this angle the septa are narrow and fall steeply within the narrow valleys, but slope more gradually within wide valleys. Between the wall and the inner ends of the septa there are from about 12 to about 14 pectinations; those near the lower ends of the septa somewhat larger and more or less divided on their tips. Thin, erect paliform lobes well developed. Their inner edges fall steeply to the periphery of a columella composed of fine, rather delicate septal trabeculæ. Septal faces beset with delicate, pointed granulations.

Endotheca highly developed, very vesicular.

Another specimen differs from the holotype chiefly in having a more distinctly hillocky surface; and some septa are thicker.

Localities.—Meyer Island, on rock; depth 1 fathom (holotype). Meyer Island, rocky and gravel bottom; depth 12 fathoms (paratype). Dayrell Islet, volcanic submarine beds.

This coral is a species of *Goniastrea*, and except that it has meandroid calicinal valleys, it bears considerable resemblance to some specimens of *G. pectinata* (Ehrenberg). *G. planulata* Milne Edwards and Haime has meandroid corallites, but its skeleton is much heavier. I know of no described coral species to which the one here considered is referable, but that it has a rather wide distribution in the Pacific Ocean is shown by a specimen from Formosa (according to the label), in the U. S. National Museum.

Studer[1] has described a coral from Singapore, to which he applies the name *Scapophyllia lobata*, which may be the same as this, but he gives the number of septa for it as 13–15 to 1 cm., while the number for *Goniastrea benhami* is 20–24 to 1 cm. If Studer meant 13–15 to apply to the larger septa the number per centimeter would be nearly the same as in the latter. A good photographic illustration of Studer's species is needed.

Genus LEPTORIA Milne Edwards and Haime.

1848. *Leptoria* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p 493.

Type species: *Meandrina phrygia* Lamarck = *Madrepora phrygia* Ellis and Solander.

Leptoria phrygia (Ellis and Solander).

Plate 45, figures 4, 5, specimens from Cocos-Keeling Islands; plate 46, figure 1, Ellis and Solander's type of *Madrepora phrygia;* figures 2, 3, specimens from Cocos-Keeling Islands.

1786. *Madrepora phrygia* Ellis and Solander, Nat. Hist. Zooph., p. 162, plate 48, fig 2.

Although the U. S. National Museum possesses Dana's types of *Leptoria tenuis* and *L. gracilis*, the suite of specimens representing the genus is too meager for an adequate study of the range in variations of the reputed species belonging to it. The present identification of the specimens obtained by Dr. Wood Jones in Cocos-Keeling is based on a photograph of Ellis and Solander's type, which is in the Hunterian Museum, Glasgow, and of which Professor J. Graham Kerr has sent me a

[1] Naturforsch. Gesellsch. Bern Mitth., Jhr. 1880, p. 34, 1881.

photograph. The type specimen has from 11 to 12 large septa to 1 cm., without or rarely with intermediate small septa, septal margins flat across the collines; width of valleys 3 to 5 mm. The Cocos-Keeling specimens have precisely these characters. *L. tenuis* (Dana) (see plate 47, figs 1, 1*a*) has more acute collines and thinner and more crowded septa, about 16 larger with a few smaller intermediates to 1 cm.; *L. gracilis* (Dana) (see plate 46, figs. 4, 4*a*) has still more crowded septa up to 26 larger to 1 cm., and has broadly triangular collines, or the upper septal margins may be flatly arched. Apparently there are three distinct species. The *Leptoria phrygia* of Milne Edwards and Haime seems to me to be the same as the second of the Cocos-Keeling specimens, which is described in a following note.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones states:

"The boulders from which specimens were taken were all collected in the 'poisoned-water area' of 1876 described by H. O. Forbes. Color while alive brownish, rapidly turns white on exposure."

The following notes from the same author relate to another specimen (plate 45, fig. 5, plate 46, fig. 3) from Cocos-Keeling:

"Pulu Tikus, rocky lagoon shore near east end; water 3 feet deep at low tide. Color, bright yellow brown while alive. Four specimens from a colony about 18 inches in diameter, upper surface lumpy and lobulate; base irregularly circular."

This coral seems to me to be the one Milne Edwards and Haime (and perhaps also Dana) referred to *L. phrygia*, as in places there are about 15 larger septa with alternating smaller to 1 cm., but this septal arrangement is not invariable, as frequently there are no smaller between the larger septa. Usually the septal margins over the collines are truncate, but in places they form low triangles. There is in places a considerable development of spongy tissue along the valley bottoms, but a lamellar columella is distinguishable in the axis. The specimen resembles *L. gracilis* in its growth-form and crowded septa, but continued comparison of it with typical *L. phrygia* has convinced me that it is a variant of the latter species and that it is not *L. gracilis*.

Distribution.—Cocos-Keeling Islands; southern Philippines (J. B. Steere); Ceylon[1] (Dana). Reliable, precise locality records are few.

Leptoria gracilis (Dana).

Plate 46, figures 4, 4*a*, Dana's type of *Meandrina gracilis*. Also plate 17, figure 34, of Dr. Mayer's article.

1846. *Meandrina gracilis* Dana, U S. Expl. Exped., Zooph., p. 261, plate 14, figs. 6, 6*a*, 6*b*.
1857. *Leptoria gracilis* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 407.

Identification is based on Dana's type from the Fiji Islands, No. 16, U. S. National Museum.

Stations, Murray Island.—Southeast reef, line I:

1,600 feet from shore, water 10 inches deep.
1,640 feet from shore, water about 14 inches deep, bottom of broken corals.

There are 3 specimens from Murray Island which show no marked variation from Dana's type. Width of valleys 3 to 4 mm., interserial walls thin or thickened up to 2 mm., on the periphery up to nearly 4 mm. Septa about 19 to the centimeter; usually equal, sometimes alternating in size; upper margins rounded or flattened; inner edges perpendicular. Septa much more crowded than in *L. phrygia* and *L. tenuis*.

Distribution.—Fiji Islands; Murray Island; Indian Ocean; Red Sea.

[1]This is named *Mæandra rudis* by Verrill, Trans. Conn. Acad. Arts and Sci., vol. 11, p. 69, 1902.

Leptoria tenuis (Dana).

Plate 47, figures 1, 1*a*, Dana's type of *Meandrina tenuis.*

1846. *Meandrina tenuis* Dana, U. S. Expl. Exped., Zooph., p. 262, plate 14, figs. 7, 7*a*–7*d*.

This appears to be a rare species. Although it was not collected in either the Cocos-Keeling Islands or at Murray Island, as it has been necessary to discuss it (see page 118), notes will be made on its distribution.

Distribution.—Fiji Islands (Dana's type, No. 62, U. S. Nat. Mus.); southern Philippines (J. B. Steere, collector), a single specimen in the U. S. National Museum. Gardiner reports it from Wakaya, Fiji Islands.

Genus MÆANDRA Oken.

1815. *Mæandra* Oken, Lehrb. Naturgesch., Th. 3, Abth. 1, p. 70.
1902. *Mæandra* Verrill, Trans. Conn. Acad. Arts and Sci., vol. 11, p. 66.

Type species: *Madrepora labyrinthiformis* Linnæus.

The species here considered all belong to the section of the genus to which Milne Edwards and Haime applied the name *Cœloria.*

Rehberg has described three supposedly new species from Australia, viz: *Cœloria elegans*, from near Rockhampton; *C. deltoides*, from Port Bowen; and *C. australiensis*, from near Rockhampton.[1] Until his types have been restudied it is not possible to know with what species he was dealing. However, it seems that his *C. elegans* and *C. deltoides* are synonyms of *Mæandra* (*Cœloria*) *lamellina* Ehrenberg; and although his figure of *C. australiensis* suggests a fungid coral of the *Pavona varians* group, it may be related to *Mæandra* (*Cœloria*) *stricta* (M. Edw. and H.).

Mæandra dædalea (Ellis and Solander).

Plate 44, figures 3, 3*a*, specimens from Murray Island; plate 45, figure 1, Ellis and Solander's type of *Madrepora dædalea.* Also plate 14, figure 20, of Dr. Mayer's article.

1786. *Madrepora dædalea* Ellis and Solander, Nat. Hist. Zooph., p. 163, plate 46, figs. 1, 2.
1857. *Cœloria dædalea* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 416.
1907. *Cœloria dædalea* Bedot, Madréporaires d'Amboine, p. 117, plate 16, figs. 70–72.

Identification is based on a photograph of the type of Ellis and Solander, furnished by Professor J. Graham Kerr.

Stations, Murray Island.—Southeast reef, line I, 1,600 feet from shore, water 10 inches deep (see plate 44, figs. 3, 3*a*). The series average shorter than usual, most of them less than 17 mm. long, but one is 29.5 mm. long; width of valleys 5 to 6 mm.; upper part of wall with some perforations. Also, from 1,632 feet from shore, water 14 inches deep at lowest tide, hard rocky bottom. This is a small, either young or stunted specimen, with much-thickened walls, up to 25 mm. (see Dr. Mayer's No. 20).

Distribution.—Indian Ocean and eastward in the Pacific to the Paumotus (Fakarava, *Albatross*, 1899–1900).

Mæandra lamellina Ehrenberg.

Plate 45, figures 2, 2*a*, from Murray Island.

1834. *Mæandra* (*Platygyra*) *lamellina* Ehrenberg, Corallenth. Roth. Meer., p. 99.
1846. *Meandrina rustica* Dana, U. S. Expl. Exped., Zooph., p. 258, plate 14, figs. 5*a*, 5*b*.
1879. *Cœloria arabica* Klunzinger, Korall. Roth. Meer., pt. 3, p. 17, plate 2, figs. 1–3; plate 9, figs. 10*a*–10*c*.

The following is a description of a specimen of the species from Murray Island:

Corallum forming massive, rounded heads.

Valleys long and winding; width 4.5 to 6 mm.; depth, 4 to 4.5 mm. Walls thin, with occasional perforations, or thickened up to 2 mm.

[1] Abhandl. Naturwiss. Verein, Hamburg, vol. 12, pp. 20–21, 1892.

Septa, 14 to 15 to centimeter, usually equal, occasional intermediate rudimentary septa. Margins steeply or broadly arched over the wall summits, falling steeply or perpendicularly to bottoms of valleys. Septal dentations well developed, serrate. Columella trabecular.

Station, Murray Island.—Southeast reef, line I, 1,600 feet from shore.

In my opinion Dana's *Meandrina rustica* from Wake Island is the same as *M. lamellina* Ehrenberg. Klunzinger has elaborately described the variation of this species. There are in the U. S. National Museum good suites of specimens from Djibouti (French Somaliland), received through Dr. Charles Gravier, and from the southern Philippines, J. B. Steere, collector. The Murray Island specimen is somewhat denser than those from the other localities, and the collines average lower.

Distribution.—Red Sea; Indian Ocean; Murray Island, Australia; southern Philippine Islands; Samoa; Wake Island. An excellent specimen collected by Mr. Carl Elschner at Fanning Island is in the U. S. National Museum. The species therefore extends from the east coast of Africa to Fanning Island.

Mæandra astreiformis (Milne Edwards and Haime).

Plate 14, figure 19, of Dr. Mayer's article.

1849. *Astroria astreiformis* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool., vol. 11, p. 299.
1850. *Cœloria astræiformis* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 417.
1899. *Cœloria astræiformis* Gardiner, Proc. Zool. Soc. London for 1899, p. 743, plate 46, fig. 4.

Description of a specimen from Murray Island:

Corallum incrusting, rounded above, about 4 cm. long and 5 cm. wide.

Valleys from 6 to 9 mm. long; 5 mm. wide. Not more than 2 calicinal centers in a valley. Walls usually with a sharp edge, but thickened below, where they are up to 2 mm. wide. Depth of valleys up to 4.5 mm.

Septa average about 1 mm. apart, usually no rudimentaries; exsert up to a little more than 1 mm.; upper edges flattened; inner edges perpendicular or overhanging, raggedly dentate.

Columella poorly developed, trabecular.

Station, Murray Island.—Southeast reef, line I, 1,620 to 1,670 feet from shore; water 15 inches deep at lowest tides; hard, rocky bottom.

It seems to me that *Cœloria astreiformis* and *esperi* of Milne Edwards and Haime must be the same species, as the only definite difference is in the thickness of the walls, which may range from a perforate membrane up to 2 mm. in thickness, as in the Murray Island specimen.

Distribution.—The species ranges from the Red Sea eastward to Wakaya, Fiji Islands.

Mæandra stricta (Milne Edwards and Haime).

Plate 45, figures 3, 3*a* specimen from Murray Island.

1857. *Cœloria stricta* Milne Edwards and Haime, Hist. nat. Corall. vol. 2, p. 417.

The following is a description of a specimen of this species from Murray Island:

Corallum with flattish upper surface, apparently incrusting.

Corallites polygonal. Walls of adjacent corallites applied one to the other, fused, or more or less imperfect. Thickness from about 0.5 to nearly 1 mm. Ends of septa in the walls often hollow, probably a pathologic character.

Calices, maximum length about 7 mm.; width 3.5 to 4.5 mm., depth, 2.5 to 3 mm.

Septa, 6 or 7 to 5 mm., less than 1 mm. apart, subequal at the wall. In a calice 6 mm. long by 4.5 mm. wide, 11 reach the columella; 3 fuse to the sides of larger septa near the columella; and 7 smaller septa, one of them rudimentary, have free edges, total number 21. Edges scarcely or not at all exsert; those of the longer septa flattened or gently sloping from the wall to near the columellar region, where they are perpendicular; smaller septa narrower and slope steeply. Margins irregularly but rather finely dentate. No pali. Very fine granulations on the septal faces.

Columella small, composed of coarse trabeculæ.
Dissepiments nearly horizontal, about 1 mm. apart.
Reproduction by equal or subequal fission, opposi e septa meeting across the columella.

Station, Murray Island.—Southeast reef, line I, 1,600 feet from shore.

Milne Edwards and Haime divide *Cœloria* into two groups, viz: § A with long and § AA with short calicular series. The second group is subdivided into § C, "walls thin," and § CC "wall a little thick." § C contains *C. dædalea*, *C. sinensis*, *C. stricta*, and *C. astræiformis*. *C. dædalea* and *C. astreiformis* are represented in the U. S. National Museum by specimens from several localities in the Indian and Pacific Oceans, and *C. sinensis* and *C. stricta* by specimens from the southern Philippines. The specimen from Murray Island accords with the marginal part of a Philippine specimen which I have referred to *C. stricta*. On the top of the corallum of the latter specimen the series are somewhat wider, longer, and deeper, and the walls are thin and perforate. The septa are more crowded than in *C. sinensis*, as Milne Edwards and Haime have stated.

Distribution.—Straits of Malacca; southern Philippines; Torres Strait.

Genus HYDNOPHORA Fischer de Waldheim.

1807. *Hydnophora* Fischer de Waldheim, Mus. Demidoff, vol. 3, p. 295, 1 plate (reference taken from Fischer de Waldheim's Oryctographie, etc.).
1810. *Hydnophora* Fischer de Waldheim, Recherches sur les Hydnophores, pp. 7–13, 1 plate.
1830–1837. *Hydnophora* Fischer de Waldheim, Oryctographie du gouvernement de Moscou, p. 155.
1857. *Hydnophora* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 418.
1901. *Hydnophorella* Delage and Hérouard, Traité de Zool. concrète, vol. 2, pt. 2, p. 628.

Type species: *Hydnophora demidovii* Fischer de Waldheim = *Madrepora exesa* Pallas.

As Fischer says, regarding his *H. demidovii*, in his "Oryctographie," "Ce beau polypier vivant, des Indes orientales, est le type du genre," it is astonishing that Delage and Hérouard should propose a new generic name for the type species, because Fischer erroneously referred some fossil corals to the genus. Fischer's figures of *H. demidovii* in his "Oryctographie" (plate 32) are excellent, and *Hydnophora* is one of the most securely established of coral genera.

Hydnophora exesa (Pallas).

Plate 47, figures 2, 2*a*, specimen from Murray Island; plate 48, figure 1, specimen from southern Philippine Islands.

1857. *Hydnophora exesa* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 420.
1874. *Hydnophora contignatio* Klunzinger, Korall. Roth. Meer., pt. 3, p. 22, plate 3, figs. 2, 3; plate 9, figs. 12*a–c*.
1906. *Hydnophora contignatio* von Marenzeller, Denkschr. k. k. Ak. Wiss. Wien, vol. 80, p. 81, plate 23, fig. 82*a*; plate 24, fig. 82.
1907. *Hydnophorella exesa* Bedot, Madréporaires d'Amboine, p. 199, plate 25, figs. 123–129.

The identification is based on figures published by von Marenzeller and Bedot.

A single small but perfect corallum was collected by Dr. Mayer.

Station, Murray Island.—Reef flat, northwest side of island, about 300 feet from shore; water about 2 inches at low tide; hard bottom.

Milne Edwards and Haime pointed out that *H. exesa*, *H. demidoffi*, and *H. polygonata* all probably represent stages or growth facies of one species, and that the difference between *H. demidoffi* and *H. lobata* is slight. Stanley Gardiner has discussed the relations of these forms,[1] and refers *H. tenella* Quelch to the synonymy of *H. exesa*. Von Marenzeller figures a specimen which he refers to *H. contignatio* (Forskål), of which, according to Klunzinger, *H. ehrenbergii* Milne Edwards and Haime is a synonym. Bedot further discusses the relations of the forms. Present

[1]Proc. Zool. Soc. London for 1899, pp. 745, 746.

evidence indicates that § A and § AA of Milne Edwards and Haime, plus *H. contignatio* (Forskål), plus *H. tenella* (Quelch), are all only stages or growth-forms of one species, *H. exesa* (Pallas).

Distribution.—Red Sea; Indian Ocean; Murray Island; Amboina; southern Philippines; Funafuti.

Hydnophora microconos (Lamarck).

Plate 47, figures 3, 3*a*, specimen from Murray Island. Also plate 18, figure 42, of Dr. Mayer's article.

1857. *Hydnophora microcona* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 423.
1907. *Hydnophorella microconos* Bedot, Madréporaires d'Amboine, p. 197, plate 25, figs. 119–122.

Specimens of this well-known species were collected at Murray Island, southeast reef, line I, as follows:

1,600 feet from shore water 10 inches deep, a perfect head, attached by a pedicellate base (see plate 47, figs. 3, 3*a*). Greater diameter 15 cm.; lesser, about 12 cm.; height, about 9.5 cm.
1,640 feet from shore, water 14 inches deep at lowest tide; hard, rocky bottom. A piece of a thriving head.
1,775 feet from shore; Lithothamnion ridge. Upper part of corallum killed and corroded; living around the edge.

Two beach-worn specimens were picked up by Dr. Wood Jones in the Cocos-Keeling Islands. He did not observe the species alive.

Distribution.—Red Sea; Indian Ocean; Murray Island; Amboina; southern Philippines; Rotuma; Wakaya (Fiji Islands); Fanning Island. A good specimen of the species collected by Mr. Carl Elschner at the last-mentioned locality is in the U. S. National Museum.

Hydnophora rigida (Dana).

Plate 48, figure 2, specimen from Fanning Island; figure 3, part of Dana's type of *Merulina rigida.*

1846. *Merulina rigida* Dana, U. S. Expl. Exped., Zooph., p. 176, plate 17, figs. 1, 1*a*–1*c*.

A figure of Dana's type is given on plate 48, figure 3. A specimen of this species collected by Mr. Elschner at Fanning Island (see plate 48, fig. 2) has thicker branches than Dana's type, and the branch terminals divide into rather short, obtuse lobules, instead of being attenuate or having attenuate subdivisions. The terminal monticules of the former are larger than those of the latter. The Fanning Island specimen has the appearance of having grown in very shallow or rough water, whereas Dana's type looks as if it lived either in quiet water or at a depth considerably below low-tide-level. Except in the characters mentioned, the two specimens closely resemble each other. The texture of both is dense, and the monticules on the older portions of the coralla are essentially alike.

Distribution.—Southern Philippines; Fiji Islands; Fanning Island. Not reported from the Indian Ocean.

Family MUSSIDÆ Verrill.

Genus MUSSA Oken.

1815. *Mussa* Oken, Lehrb. Naturgesch., Th. 3, Abth. 1, p. 73.

Type species: *Madrepora angulosa* Pallas, from Curaçao.

Oken mentions three species as belonging to his *Mussa*. The first is *M. dianthus*, with which he associated *Madrepora lacera* and a fossil from Swabia; the second is the *Madrepora angulosa* of Pallas; and the third is *Madrepora fastigiata*, which was later referred to *Eusmilia* by Milne Edwards and Haime. The *Mussa dianthus* of Oken is probably *Caryophyllia dianthus* (Esper) M. Edw. and H. The genotype, therefore, must be *Mussa angulosa* (Pallas), a species very abundant around Curaçao.

Mussa sinuosa (Lamarck).

Plate 49, figure 1, type of Ellis and Solander's *Madrepora angulosa* γ; figure 2, probably the type of Dana's *Mussa costata*; figure 3, type of Dana's *Mussa cytherea;* plate 50, figures 1, 1*a*, 1*b*, specimen from Murray Island.

1786 *Madrepora angulosa* γ Ellis and Solander, Nat. Hist. Zooph., p. 153, plate 34 (non *Madrepora angulosa* Pallas.)
1816. *Caryophyllia sinuosa* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 229.
1846. *Mussa costata* Dana, U. S. Expl. Exped., Zooph., p. 179, plate 7, figs. 2, 2*a*, 2*b*.
1846. *Mussa sinuosa* Dana, U. S. Expl Exped., Zooph., p. 179, plate 8, figs. 1, 1*a*–1*c*.
1846. *Mussa cytherea* Dana, U. S. Expl. Exped., Zooph., p. 180, plate 7, figs. 3*a*–3*c*.
1857. *Mussa sinuosa* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 333.
1886. *Mussa brueggemanni* Quelch, Reef Corals, *Challenger* Reports, p. 79, plate 2, figs. 6–6*b*.
1907. *Mussa brueggemanni* Bedot, Madréporaires d'Amboine, p. 180, plate 17, figs. 76–83.

Identification based on photograph of Ellis and Solander's type, kindly furnished by Professor J. Graham Kerr of the University of Glasgow.

The specimen from Murray Island (plate 50, figs, 1, 1*a*, 1*b*) was in an unhealthy condition; it was partly dead, and had been stunted by an adverse environment. Therefore it is not typical. The edge zone extends only a short distance below the calice, 5 or 6 mm., but some strong spines persist on the costæ. The spines on the septal arches are similar to those of the type of *M. sinuosa*, and between the larger, thicker septa are usually from 3 to 5 smaller ones, ranging in size according to cycle. On the lower edges of the septa are a few, 1 to 3, conspicuous teeth, and the smaller septa have finer dentations on their margins. The columella is poorly developed, composed of a few coarse trabeculæ.

Station, Murray Island.—Southeast reef, line I, 1,000 feet from shore; water 17 inches deep.

It appears from Lamarck's description that he based this species primarily on Ellis and Solander's figure. Professor J. Graham Kerr has sent me a photograph of Ellis and Solander's type (plate 49, fig. 1). The width of the calices ranges from 18.5 to about 30 mm. Septa, 5 to 7 to the centimeter. There are large, thick septa, up to 2 mm. thick, with margins strongly exsert, up to 5.5 mm., upper edges with strong teeth, below prominent shorter, distant subacute or rounded teeth to near the columella. Smaller septa, either singly or in groups of from 3 to 5 between the larger; these are thinner, not so exsert, and have slender teeth on their margins to the columella where they extend so far inward. Columella lax, composed of septal trabeculæ. Costæ distinct, alternating in size, some with prominent spines.

The U. S. National Museum has about 45 specimens of this species from the southern Philippine Islands, collected by J. B. Steere. The range in width of the calices, length of series, and density of corallum is great, but the character of the septal dentation is constant for the series. Quelch's *Mussa brueggemanni* is a part of the series; and from Klunzinger's descriptions and figures of *Mussa hemprichi* Ehrenberg, it is only a form of *M. sinuosa.*

There is some doubt regarding Dana's type of *Mussa costata.* Specimen No. 43 of the Exploring Expedition corals was labeled by Dana "*M. sinuosa ?*, Tahiti," but Dana did not in his report assign any coral to *M. sinuosa* (Lamarck). As this specimen came from Tahiti, and accords both with the description and figures of *M. costata*, it seems to be the type. It is represented by plate 49, figure 2. Comparison with the figures of Ellis and Solander's *Madrepora angulosa* var. γ =*Mussa sinuosa* (Lam.) shows that they are the same species, of which the specimen from Murray Island is only a stunted colony.

The specimen of *M. costata* stands midway between *M. brueggemanni* Quelch and *M. cytherea* Dana (see plate 49, fig. 3). At one time I thought the latter separable from *M. sinuosa* by its narrower valley, and the usual absence of prominent dentations on the lower part of the margins of the largest septa, but as such denta-

tions are sometimes present there is no break between it and *M. costata*. The development of the septal teeth on the lower margins of the principal septa appears to be correlated with the width of the valleys. Klunzinger's *Mussa distans* is a synonym of *M. cytherea*.

Mussa cactus Dana (type No. 44, U. S. Nat. Mus.) (synonym of *M. corymbosa* Forskål), *Mussa cerebriformis* Dana (type No. 11, U. S. Nat. Mus.), and *Mussa multilobata* Dana (type No. 41, U. S. Nat. Mus.) are different species, and as they are not represented in the collections from Murray Island and Cocos-Keeling Islands, they need be only mentioned in this paper.

Distribution.—Red Sea; Murray Island; Amboina; southern Philippines; Fiji Islands; Tahiti.

Genus SYMPHYLLIA Milne Edwards and Haime.

1848. *Symphyllia* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p. 491.

Type species: *Meandrina sinuosa* Quoy and Gaimard = *Mussa nobilis* Dana = *Symphyllia nobilis* (Dana).

The genus *Symphyllia* is poorly represented in the collections of the U. S. National Museum. There are of Dana's specimens, which he placed in the genus *Mussa*, *S. crispa* (Lam.), No. 86 (subsequently referred to *S. radians* M. Edw. and H. by Verrill); *S. recta* (Dana), type, No. 9; and *S. nobilis* (Dana), No. 7. Dana proposed the name *nobilis* for *Meandrina sinuosa* Quoy and Gaimard, 1833, as one of Lamarck's species (1816) had been referred to *Mussa*. Dana says (p. 188): "The name *sinuosa*, being elsewhere in use [in the genus *Mussa*] has above been changed." There is another reason for discarding the *sinuosa* of Quoy and Gaimard, for their name was based on a misidentification of Le Sueur's *Meandrina sinuosa* from the West Indies. The specimen identified by Dana from Wake Island is, as he has stated, worn, and it is not the type of the species. It seems to me that the latter specimen is probably the same as *S. indica* M. Edw. and H. The specimen identified by Dana as *Mussa crispa* is in excellent condition. It is a young colony of *S. indica*, as identified by Bedot. There are six good specimens of *S. indica* in the National Museum, collected in the southern Philippines by J. B. Steere. Dana's type of *S. recta* is badly worn. It is very close to *S. indica* and, should the two names apply to the same species, Dana's *recta* would prevail over *indica*.

Symphyllia nobilis (Dana) is represented by three specimens from the southern Philippines, collected by J. B. Steere, and two fragments collected by Dr. Mayer at Murray Island. These are considered in more detail in the succeeding description.

Professor Verrill has referred *Symphyllia* to the synonymy of *Mussa*.[1] From the specimens of *Mussa* and *Symphyllia* which I have seen, I would adhere to the usage of Milne Edwards and Haime, and am therefore treating them as distinct genera.

Symphyllia nobilis (Dana).

Plate 17, figure 35, of Dr. Mayer's article.

1833. *Meandrina sinuosa* Quoy and Gaimard, Zooph., Voy. de *l'Astrolabe*, Zool., vol. 4, p. 227, plate 18, figs. 4, 5 (*non* Le Sueur, 1820).
1846. *Mussa nobilis* Dana, U. S. Expl. Exped., Zooph., p. 187.
1857. *Symphyllia sinuosa* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 370.
1899. *Symphyllia sinuosa* Gardiner, Proc. Zool. Soc. London for 1899, p. 738, plate 48, fig. 1.
1904. *Symphyllia sinuosa* Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., vol. 2, p. 760, plate 59, figs. 1, 2, 3.
1907. *Symphyllia sinuosa* Bedot, Madréporaires d'Amboine, p. 189, plate 21, figs. 99–105; plate 22, figs. 106–110

[1]Trans. Conn. Acad. Sci., vol. 11, p. 115, 1902.

The following is a description of a specimen from Murray Island:

Corallum with gently convex upper surface.

Collines obtuse; along the summit there is a furrow to which the outer ends of the septa extend. Width of intercorallite walls 4.5 to 8 mm.

Width of series, 13 to 17 mm.; length, 60 to 70 mm.; depth of valley, 5.5 mm.

Septa 10 to 1 centimeter, usually alternating in size, thickened in the wall. The large septa thick, extend to axes of valleys, upper edges arched or flattish; inner edges slope to bottoms of valleys; smaller septa, thin within valleys, do not reach the axis. Two or three thick not very prominent teeth on outer edges of large septa; two to five teeth on edges within the valleys, the uppermost the more prominent and sometimes hollow. Maximum length of teeth 1.25 mm. Septal faces densely beset with small granulations.

Columella, flat above, composed of closely twisted trabeculæ; diameter about 2 by 3 mm. Distance apart in valleys about 7 mm. One or two axial septa connect the columellæ of adjacent polypites.

Exotheca composed of arched thick-walled vesicles. Endothecal dissepiments about 1.5 mm. apart.

Stations at Murray Island.—Southeast reef, 1,600 feet from shore, water 10 inches deep; and at 1,625 feet from shore, water 14 inches deep at lowest tides; hard, rocky bottom.

It has already been stated that Dana's *Mussa nobilis* is a renaming of *Meandrina sinuosa* Quoy and Gaimard. The Murray Island specimens appear undoubtedly to belong to the same species as the specimens referred to *Symphyllia sinuosa* by Bedot, but they do not precisely accord with typical specimens. The suite in the U. S. National Museum is small, comprising only three specimens, from the southern Philippines. The principal difference between these and the Murray Island specimens is in size, the valleys in the typical specimens being wider and deeper, the septal dentations larger, and the interserial wall sharper. However, around the edges of one Philippine specimen the differences from Murray Island specimen are slight. Width of valleys as small as 11 mm., depth 6 mm. The septal dentations of the former are coarser than those of the latter but of the same pattern and arrangement. Although there are the differences indicated, they are of the kind that may be produced by vegetative causes, and therefore can scarcely be considered of specific value.

Symphyllia indica is closely related to the *S. nobilis*, notwithstanding its wider and deeper valleys, and apparently is not beyond the range of specific variation. *S. acuta* Quelch is also close. However, until large suites of specimens have been carefully studied and compared with one another, attempts to determine specific limits and synonymies would be futile.

Distribution.—Maldives, Singapore, and Rotuma (Gardiner); Murray Island; Amboina (Bedot); southern Philippines (J. B. Steere); New Mecklenburg (Quoy and Gaimard). Not reported from the Red Sea or east of Rotuma.

Genus ACANTHASTREA Milne Edwards and Haime.

1848. *Acanthastrea* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 27, p. 495.

Type species: *Acanthastrea spinosa* Milne Edwards and Haime, which is the same as *Astræa echinata* Dana.

Acanthastrea echinata (Dana) var.

Plate 50, figs. 2, 2*a*, and plate 51, fig. 1, Dana's type of *Astræa echinata;* plate 51, fig. 2, var. from Murray Island.

1846. *Astræa echinata* Dana, U. S. Expl. Exped., Zooph., p. 229, plate 12, figs. 1, 1*a*–1*b*.
1857. *Acanthastræa ? echinata* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 504.
1914. *Favia hirsuta* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 100, plate 24, figs. 7, 8.

Dana's type, from the Fiji Islands, is in the U. S. National Museum, No. 35, and there are 3 other specimens from Hereheretue, Paumotus. As the specimen from Murray Island differs from the type and other typical specimens, it will be described as follows:

Corallum an incrusting, subquadrangular plate, about 13 cm. wide, 15 cm. long, and 3 cm. thick in the center, thinner on the edge.

Corallite walls fused, solid, about 3 mm. thick.

Calices polygonal, subelliptical, or suboval. Lesser diameter 9 to 13 mm.; greater, up to 17.5 mm., 15 mm. usual. Depth, 6 or 7 mm.

Septa thickened in the walls, directly continuous between adjacent calices, or ends separated by an obscure groove. Narrow above, sloping steeply to near level of columella, where they widen. Number in a calice 13 by 15 mm. in diameter, 20 reach the columella, about 17 project half-way or farther to the columella, 6 shorter septa, total number 43. Outer ends of all septa subequal in thickness, there being no regular alternation in size. Inner parts thin. Members of higher cycles frequently fuse to the sides of those of the lower, forming groups of 3 to 5 septa.

Septal margins, spinose on and near the wall, spines slender, up to 1.5 mm. long. Usually a spine on the top of the wall, or one on each side of the top, with one or two prominent spines near the top of each septal edge within the calice; the lower dentations serrate, less prominent, often a slight increase in length near the columella. There are no definite paliform lobes. Septal faces smooth or nearly smooth, granulations when present small and scattered.

Columella small, poorly developed, trabecular, only about one-fifth the diameter of that of a calice.

Reproduction by subequal fission, a wall forming across and separating two polypite centers.

Station, Murray Island.—Lithothamnion ridge.

Matthai[1] places *Astrea dipsacea* Lam., *Acanthastrea hirsuta*, *spinosa*, *brevis*, and *grandis* of Milne Edwards and Haime, and *Acanthastrea irregularis* Quelch in the synonymy of *Favia* (*Acanthastrea*) *hirsuta* (M. Edw. and H.). *Acanthastrea echinata* Dana differs from Matthai's description chiefly in having the sides of the septa closely granulate, and in usually having the septa of adjacent calices continuous across the wall. In these characters the specimens from the Paumotus accord with Dana's type. The figures published by Matthai (plate 24, figs. 7, 8) show septa usually continuous across the wall, but do not show the character of the septal faces. I doubt the last-mentioned character being of specific value, as it is evidently variable. Therefore, should Audouin's name *dipsacea* not have been intended to apply to this species, Dana's name *echinata* would be the proper one.

Distribution.—Red Sea; Maldives; Murray Island; Tongatabu; Fiji Islands; Paumotus.

GENUS NOT REFERRED TO ANY FAMILY.

Genus MERULINA Ehrenberg.

1834. *Merulina* Ehrenberg, Corallenth. Roth. Meer., p. 104.

Type species: *Madrepora ampliata* Ellis and Solander.

Dana referred 8 species to *Merulina*, as follows: *M. ampliata* (Ell. and Sol.), *M. regalis* Dana, *M. speciosa* Dana, *M. crispa* Dana, *M. folium* (Lam.), *M. scabricula* Dana, *M. laxa* Dana, and *M. rigida* Dana. His types or original specimens for all of them, except *M. folium*, are in the U. S. National Museum. All the species except *M. folium* and *M. rigida*, which belong to *Hydnophora*, are still retained in the genus. *M. folium* is a synonym of *H. exesa* (Pallas), while *M. rigida* is considered a valid species.

[1]Trans. Linn. Soc. London, 2d. ser., Zool., vol. 17, pp. 100–102, 1914.

Merulina ampliata (Ellis and Solander.)

Plate 52, figures 1, 1*a*, 1*b*.

1857. *Merulina ampliata* Milne Edwards and Haime, Hist. nat. Corall., vol. 2, p. 628.

There is in the U. S. National Museum, from Torres Strait, a specimen of *Merulina* which is undoubtedly *M. ampliata*. Plate 52, figs. 1, 1*a*, 1*b*, represent three views of it. The collines are usually narrow, as in Ellis and Solander's type, two photographs of which have been kindly sent me by Professor J. Graham Kerr of the University of Glasgow. The collines in the specimen referred by Dana to *M. ampliata* are mostly round, as he observes, while in *M. regalis* they are either round or acute.

Distribution.—Maldives (Gardiner); East Indies; Torres Strait.

MADREPORARIA FUNGIDA.[1]

Family FUNGIIDÆ Dana.

Genus FUNGIA Lamarck.

1801. *Fungia* Lamarck, Syst. Anim. sans. Vert., p. 369.
1902. *Fungia* Döderlein, Korallengat. Fungia, Abhandl. Senckenb. naturf. Gesellsch., vol. 27, pt. 1, pp. i–iii, 1–162, 25 plates.
1905. *Fungia* Vaughan, Proc. U. S. Nat. Mus., vol. 28, p. 380.
1907. *Fungia* Vaughan, U. S. Nat Mus. Bull. 59, pp. 110–134.
1909. *Fungia* Gardiner, Trans. Linn. Soc. London, 2d ser., Zool., vol. 12, p. 263.

Type species: *Madrepora fungites* Linnæus.

Fungia aff. F. concinna Verrill.

1902. *Fungia plana* Döderlein, Korallengat. Fungia, p. 111, plate 11, figs. 2–5.
1902. *Fungia concinna* Döderlein, Korallengat. Fungia, p. 113, plate 12, figs. 1–2; plate 13, fig. 4.
1909. *Fungia concinna* Gardiner, Trans. Linn. Soc. London, 2d ser., Zool., vol. 12, p. 276.

A single attached anthocyathus is 22 mm. long by 21.5 mm. wide, and has an imperforate, finely costate base. Costæ regularly alternate in size and have finely granulate edges. Septal margins microscopical dentate. Twelve principal septa, smaller septa in anastomosing groups between the principals. Five complete cycles, and in some quarter systems the sixth cycle is complete. The resemblance to the *Fungia patella* group is close. Because of the immaturity of the specimen, a positive identification is not attempted.

Station, Murray Island.—Southeast reef, line I, 1,445 feet from shore; water 14 inches deep at lowest tide; hard, rocky bottom, no sand.

Distribution of F. concinna (taken from Gardiner).—Red Sea; East Africa; Seychelles; Chagos; East Indies; Philippines; New Britain; Pacific.

Fungia fungites (Linn.).

1902. *Fungia fungites* Döderlein, Korallengat. Fungia, p. 136, plates 20–25 (all figs.).
1910. *Fungia* Wood Jones, Coral and Atolls, p. 58, text-figs. 2, 3.

The following description is based on a specimen from Murray Island:

Disk slightly arched above, and somewhat concave below, 170 mm. long, about 150 mm. wide, height 48 mm.

Septa, on the edge of the disk, about 12 to 1 cm.; every third or sixth usually thicker and more prominent than those intermediate, usually 5 intermediate thin septa between the thicker, but the number of the thin septa ranges from 2 to 7. Fairly prominent tentacular lobes on all, except the longest and next to the longest. About 28 septal ends around

[1]For a critical review of the simple genera of the Madreporaria Fungida, see Vaughan, Proc. U. S. Nat. Mus., vol. 28, pp. 371–424, 1905. The review of the colonial genera has not been completed.

the fossa. Depth of fossa, about 12 mm. Septal margins nearly equal in height, the long septa slightly the more prominent. Large septa with from 5 to 7 serrate dentations to 1 cm.; small septa with up to 10 similar dentations.

Base abundantly perforate, costæ distinct only near the edge. Spines styliform, sides smooth, protruding trabeculæ on the tips; smallest near the margins; tallest in a zone outside the detachment scar, where a number are compound. Maximum length, 5 mm.; diameter of bases of large spines, 1 mm.

This is the *Fungia confertifolia* of Dana, which Döderlein recognizes as one of the varieties of *F. fungites*.

There is a second specimen of *Fungia*, 50 mm. long by 41.5 mm. wide, which had just been detached from the anthocormus. It is immature, but as it has some slits in the wall, a few small costal spines with smooth sides, serrately dentate septa, and tentacular lobes, it probably belongs to *F. fungites*.

Station at Murray Island.—Southeast reef, line I, 1,000 feet from shore; water 17 inches deep.

Two large specimens and a recently detached anthoblast were obtained by Dr. Wood Jones in Cocos-Keeling Islands. Greater diameter of the largest specimens, 186.5 mm.; lesser diameter, 160 mm. Greater diameter of the second large specimen, 154 mm.; lesser diameter, 149 mm.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones made the following notes:

"Not at all common, found unattached in barrier and lagoon pools, usually 2 or 3 together. It would be uncommon to find half a dozen in an afternoon's walk over the inner edge of the barrier at low tide. While living the color is pinkish brown, in some places having a greenish tinge. The largest specimen was kept alive for a long time and became more pigmented as its vitality lessened."

Distribution.—From Red Sea and the east coast of Africa eastward to Tahiti and Samoa.

Fungia scutaria Lamarck.

1902. *Fungia scutaria* Döderlein, Korallengat. Fungia, p. 91, plate 8, figs. 1–6.
1903. *Fungia scutaria* Vaughan, U. S. Nat. Mus. Bull. 59, p. 131, plate 28, figs. 3, 3*a*, 3*b*; plates 29, 30, 31, 32 (all figs.).

Two specimens from Cocos-Keeling, both with greatly developed tentacular lobes, but one is strongly arched, while the other is flat. Specimen No. 1 is 147 mm. in greater diameter, 104 mm. in lesser diameter, and 76.5 mm. in height. Specimen No. 2 is 129 mm. in greater diameter, 90 mm. in lesser diameter, and 35 mm. in height. The septal dentations of No. 2 are a little larger than those of No. 1, and in places are ragged, the condition apparently being due to injury. No. 1 is var. *dentigera* Leuckart, while No. 2 is var. *placunaria* Klunzinger, following the treatment of Döderlein.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones states:

"Not at all a common form, occurs mostly in pools on the inner edge of barrier flats. It is not found more than once or twice in a mile of barrier; but where one is found others are almost certain to be near. While alive the color is a delicate pink, becomes more pigmented under adverse circumstances."

This species is found in holes 5 to 15 feet deep, on the reefs off Pukoo, Molokai, Hawaiian Islands.[1]

Distribution.—Red Sea; east coast of Africa; Indian Ocean; tropical Pacific to Fanning and Hawaiian Islands. Mr. Carl Elschner collected the species in Fanning Island.

[1]Vaughan, *op. cit.*, p. 26 (quotation from J. F. G. Stokes).

Genus HERPETOLITHA Eschscholtz.

1825. *Herpetolitha* Eschscholtz, Isis for 1825, p. 746.
1860. *Herpetolitha* Milne Edwards, Hist. nat. Corall., vol. 3, p. 23.
1909. *Herpetolitha* Gardiner, Trans. Linn. Soc. London, 2d ser., Zool., vol. 12, p. 282.

Type species: *Madrepora limax* Esper.

Four species of this genus are in the U. S. National Museum, viz, *H. limax* (Esper), *H. foliosa* (Ehrenberg), *H. crassa* (Dana), and *H. stricta* (Dana). As the last-mentioned species has never been adequately illustrated, figures of it are published, plate 5, figures 2, 3*a*, 3*b*, and a description of it follows the remarks on *H. crassa*.

Herpetolitha crassa Dana.

Plate 53, figures 1, 1*a*, Dana's type of *Herpetolithus crassus;* plate 54, figure 1, specimen from Cocos-Keeling Islands.

1846. *Herpitolithus crassus* Dana, U. S Expl. Exped., Zooph., p. 310, plate 20, figs. 5, 5*a*–5*c*.
1898. *Herpetolitha crassa* Gardiner, Proc. Zool. Soc. London for 1898, p. 529.
1909. *Herpetolitha crassa* Gardiner, Trans. Linn. Soc. London, 2d ser., Zool., vol. 12, pt. 4, p. 286.

Type in U. S. National Museum, No. 160, see plate 53, figures 1, 1*a*.

Dr. Wood Jones collected one excellent specimen in Cocos-Keeling Islands. Its dimensions are as follows: Length, 314 mm.; width at wider end, 157 mm., median, 125 mm., narrower end, 130 mm.; height, 92 mm.; depth of concavity of under surface, 61 mm.

Gardiner has properly presented the diagnostic characters of the species.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones says of the specimen collected by him:

"From the southwest part of the lagoon, lying free in a pool. The only colony seen in the atoll. None of the island residents knew it and the native who first saw it tried to spear it (the spear mark is on the specimen). An old specimen is preserved in the Governor's house. While alive it was brownish in color, turning paler as it was exposed to the sun and air."

The specimens reported by Gardiner from Funafuti were light brown, with dark bands around the mouths while alive. Dana's figure of the species shows it to be brown with green around the mouths.

Distribution.—Cocos-Keeling Islands; Fiji Islands (Dana's type); Funafuti (Gardiner).

Herpetolitha stricta Dana.

Plate 51, figures 3, 3*a*, 3*b*, Dana's type of *Herpetolithus strictus*.

1846. *Herpetolithus strictus* Dana, U. S. Expl. Exped., Zooph., p. 309, plate 21, fig. 1.

The following is a description of Dana's type No. 161, U. S. National Museum:

Corallum oblong; 195 mm. long; 65 mm. wide; 48 mm. tall; cavity of base, 18 mm. deep.

The axial furrow extends completely from one end to the other. The central calice is 9 mm. deep, 22 mm. long, and 3 mm. wide; it is surrounded by the inner nearly perpendicular edges of about 28 large septa, between each pair of which is 1 or 3 septa of higher cycles. The calice on each side next the central one is 14 mm. long, and there are 10 to 12 large septa; 9 large septa to 1 cm. As the ends are approached the calices decrease in length and gradually become less distinct.

The upper margins of the large septa are flat above, subhorizontal, not arched as is usual in *H. limax*. The edges are finely dentate, sides finely granulate; synapticulæ obvious from above. Secondary calicinal centers are developed as close as 8 mm. to the axial furrow, and are more distinctly radiate than in *H. limax*.

The lower surface shows a solid center, which is 46 mm. long by about 16 mm. wide, and is covered by short, thick spines without regular arrangement. Outside the central area there are numerous slit-like perforations between the costal ends of the septa, and stout spines are arranged along the costæ. Plate 32, figure 3*a*, an enlarged view of the spines, shows that their ends are granulate.

Locality of the type.—Tahiti, U. S. Exploring Expedition.

The *Albatross* expedition, 1899–1900, collected 12 specimens at Papeete, Tahiti. Of these specimens, two have one of the ends bifurcate. The following table gives the dimensions and notes on the others which are of normal form:

Dimensions of specimens of Herpetolitha stricta.

No.	Length.	Breadth.	Height.	Remarks.
	mm.	*mm.*	*mm.*	
1	About 100	40	24	One end broken; middle higher than ends.
2	115	41	25	Ends turned up.
3	120	49	20	Ends higher than the middle.
4	167	61 5	32	Do.
5	204	67	39	One end slightly elevated.
6	212	67	40	Do.
7	257	93	45	Do.
8	274	74–92	50	Do.
9	270	90	65	Ends depressed; middle arched
10	317	106–116	53	Ends slightly elevated; neither touched the table top.

The axial furrow extends to both ends in specimens 1, 2, 3, 4, 5, and 6; to one end but not to the other in 9 and 10; it reaches neither end in 7 and 8. Specimens 3, 5, 7, 8, and 10 have the margins of some or many septa pathologically thickened, apparently the result of injury.

This species is obviously most nearly related to *H. limax*, but differs from the latter by having more crowded large septa, the upper margins of which are flat, not conspicuously arched, next the axial furrow; secondary calices develop nearer the furrow and are more distinctly radiate. All the suite from Papeete show the same relative crowding and the flat upper margins of the septa. I have not seen specimens which show intergradation with *H. limax*.

Distribution.—Tahiti; also Jaluit, Marshall Islands (*Albatross*, 1900), 1 specimen.

Herpetolitha limax (Esper).

1909. *Herpetolitha limax* Gardiner, Trans. Linn. Soc. London, 2d ser., Zool., vol. 12, p. 284, plate 28 figs. 20–23; plate 39, figs. 24, 25.

While discussing the species of *Herpetolitha*, it may be said that a good specimen of *H. limax* was collected by the 1908 expedition of the *Albatross* at South Lagoon, Towindao Island, Philippines; and J. B. Steere collected a suite of 4 or 5 specimens at other localities in the Philippines. As Bedot's *H. limax*[1] from Amboina seems to me correctly identified, Amboina may also be added to the list of authentic localities for this species. I agree with Gardiner's suggestion that the records for the Fiji Islands and Tahiti need verification.

Genus POLYPHYLLIA de Blainville.

1909. *Polyphyllia* Gardiner, Trans. Linn. Soc. London, 2d ser., Zool., vol. 12, p. 287 (with synonymy).

Type species: *Polyphyllia pelvis* Quoy and Gaimard, which Gardiner considers a synonym of *Fungia talpina* Lamarck.

Polyphyllia talpina (Lamarck).

Plate 54, figure 2, specimen from Murray Island.

1857. *Cryptabacia talpina* Milne Edwards and Haime, Hist. nat. Corall., vol. 3, p. 22.
1907. *Cryptabacia talpina* Bedot, Madréporaires d'Amboine, p. 226, plate 34, figs. 174–176; plate 35, figs. 177–179.
1909. *Polyphyllia talpina* Gardiner, Trans. Linn. Soc. London, 2d ser., Zool., vol. 12, p. 287, plate 36, fig. 13; plate 38, figs. 18, 19; plate 39, fig. 26.

[1]Madréporaires d'Amboine, p. 223, plate 33, figs. 169–173, 1907.

Dr. Mayer collected a single specimen of this well-known species. Its length is 20 cm.; width 5.8 to 8 cm.; height 7.8 cm. Longitudinal axis of corallum arcuate; upper surface arched; lower surface concave; ends wider than the median portion. Vertical distance between calicinal centers up to 8 mm.; horizontal distance usually less, 4 to 6 mm. Parts of the upper surface damaged.

Station, Murray Island.—Southeast reef, line I, 1,400 feet from shore; water about 15 inches deep at lowest tides.

Distribution.—Singapore (Gardiner); Philippines (U. S. Nat. Mus.); Amboina (Quelch, Bedot); New Holland and Vanikoro (Quoy and Gaimard). Apparently confined to the western Pacific and eastern Indian Oceans.

Family AGARICIIDÆ Verrill.

Genus PACHYSERIS Milne Edwards and Haime.

1849. *Pachyseris* Milne Edwards and Haime, Acad. Sci., Comptes rend., vol. 29, p. 72.

Type species: *Agaricia rugosa* Lamarck.

Besides a good suite of *P. rugosa* from the southern Philippines, there are in the U. S. National Museum Dana's types of *P. speciosa* and *P. levicollis*, and Verrill's type of *P. monticulosa* (= *P. valenciennesi* M. Edw. and H.). The columella is false, formed by axial expansions of the inner ends of the septa, which may produce a more or less lamellate columella or the axis of the valley may be solidly filled. Synapticulæ are well developed.

Pachyseris speciosa (Dana).

Plate 54, figures 3, 3*a*, Dana's type of *Agaricia speciosa*; figures 4, 4*a*, specimen from Murray Island.

1846. *Agaricia speciosa* Dana, U. S. Expl. Exped., Zooph., p. 337, plate 21, fig. 7.
1857. *Pachyseris speciosa* Milne Edwards and Haime, Hist. nat. Corall., p 86.

Identification based on Dana's type, No. 199, U. S. National Museum.

A single young specimen, of which the following is a description, was obtained by Dr. Mayer:

Corallum 28 mm. tall, attached by an expanding base, 35 mm. long by 25 mm. wide; above it, a peduncle, 25 by 22 mm. in diameter and 6 to 7 mm. high. From the top of the peduncle a thin, infundibuliform lamina extends on all sides, margins subcircular, diameter about 70 mm. Thickness from a knife-edge to 1 mm. in valleys, and 1.5 to 5 mm., or somewhat more, on the collines. Lower surface naked, no corallites and no epitheca; very finely costate; costæ near the margin either alternate in prominence or arranged in three sizes, but all are small, 18 to 5 mm.; of these 9 larger and 9 smaller; sides and edges microscopically granulate. Common wall imperforate.

Width of valleys 2.5 to 3 mm.; height of collines 0.5 to 3 mm.; taller near the center, concentrically arranged, very few monticules, summits rounded; no recognizable calicinal centers. Oral axes at the distal bases of the collines.

Septa correspond to the costæ, imperforate, equal in prominence and thickness, directly continuous across collines, edges microscopically dentate. Granulations crowded; just below septal edges form wings which may fuse from one septum to the next, forming a platform. Synapticulæ present.

Processes from inner ends of the septa fuse along the valley axes and form an almost continuous flat floor.

Station, Murray Island.—Off the northwest reef, depth 15 fathoms; rocky bottom.

This specimen is absolutely typical *P. speciosa* (Dana) except that in its shape the type is a reniform lamina. Besides this species, the U. S. National Museum contains Dana's type of *P. levicollis*, No. 190, and his *Agaricia rugosa* is represented by two specimens, Nos. 217 and 218, one of which, No. 218, is his figured specimen.

Milne Edwards and Haime proposed *Pachyseris valenciennesi* for Dana's *rugosa*, considering it a different species from the one named by Lamarck. Verrill[1] proposed the name *monticulosa* for the same species. Quelch considered the *P. speciosa* of Milne Edwards and Haime different from Dana's, and proposed *P. haimei*[2] for it. Therefore the following species are supposed to be recognizable: *P. rugosa* (Lam.), *P. speciosa* (Dana), *P. levicollis* (Dana), *P. valenciennesi* M. Edw. and H. (= *P. monticulosa* Verrill), *P. involuta* Studer,[3] and *P. haimei* Quelch, and I am here adding a species, *P. torresiana*, from Torres Strait.

Distribution.—East Indies (Dana); Murray Island; Tahiti (Quelch).

Pachyseris torresiana, new species.

Plate 55, figures 1, 1*a*.

The following is a description of the type specimen of *Pachyseris torresiana:*

Basal part of the corallum an undulating plate, with irregularly sinuous margins, 19 cm. in diameter and up to 18 mm. thick. Thickness on the edge 0.75 to 1.5 mm. No area of attachment shows on the type, but it was probably attached on the side now broken. The lower surface shows no perforations, there are fine costæ alternating in size, and although in general naked, apparently in places there are a few epithecal threads.

On the upper surface there are undulating areas on which are long, rather straight or sinuous collines, and tall flabellate crests, on which are collines similar to those on the less-elevated part of the corallum. Two crests may fuse by their edges. Height of the crests up to 95 mm.; width of single crests up to 40 mm.; width of two crests fused into one, 50 mm. or more. The maximum width of a crest, when fully developed, is approximately twice that near its base. Thickness of crests just below the edge, about 1.5 mm.; just above the base, about 15 mm.

Width of valleys, between top of adjacent collines, from 1.75 mm. to 3.5 mm., 2.5 to 3 mm. usual. Collines, height 2.5 mm.; profile triangular, with the apex slightly blunted.

Septa continuous across collines, equal, crowded, 18 to 19 within 5 millimeters, occasionally slightly kneed on the colline summit. Sides densely beset with blunt granulations.

Columella a distinct longitudinal lamella, except near the growing edge. It is formed of septal processes developed along the axis of the valley floor.

Type: U. S. National Museum.

Locality.—Torres Strait, Australia.

This is so strikingly different from any of the other species that critical comparison is scarcely necessary. None of the others known to me has its high, more or less spatulate crests or its lamelliform columella.

Genus PAVONA Lamarck.

1801. *Pavona* Lamarck, Syst. Anim. sans. Vert., p. 372.

Type species: *Pavona cristata* Lamarck = *Madrepora cristata* Ellis and Solander = *Lophoseris knorri* Milne Edwards and Haime = *Pavona formosa* Dana = *Pavona cactus* (Forskål).

According to Klunzinger,[4] *Madrepora cristata* Ell. and Sol. = *Madrepora cactus* Forsk., while he describes the *Lophoseris cristata* of Milne Edwards and Haime as *Pavonia angularis* Klz. It therefore seems that the name *cristata* has been applied to two species which now bear the names *P. cactus* (Forsk.), and *P. danai* (M. Edw. and H.).

I believe *P. knorri*, evidently based on Knorr's plate AX, figure 1, the same as Dana's *P. formosa*, which, judging from the figures published by Klunzinger and

[1]Dana, Coral and Coral Islands, p. 383, 1872.

[2]Reef corals, *Challenger* Reports, p. 124.

[3]Köngl. Akad. Wissensch. Berlin, Monatschr. für 1877, p. 644, pl. 3, fig. 11.

[4]Korall. Roth. Meer., pt. 3, pp. 73, 74, 1879.

von Marenzeller, is the same as *P. cactus* (Forsk.). (I doubt the correctness of Milne Edwards and Haime's statement that *P. knorri* has no columella.) As it is important that this synonymy should be straightened out, I am publishing (plate 56, figs. 1, 1*a*) figures of the terminal part of a frond of *P. formosa* Dana, on natural scale and twice natural size, so that it may be compared with plate 42, figure 77, of von Marenzeller's *Pola* corals, and with Klunzinger's plate 9, figure 2. *Pavona danai* M. Edw. and H., *P. complanata* Verrill, *P. angularis* Klz., and *P. laxa* Klz., will be discussed under *P. danai*, of which they are synonyms.

The collection of specimens of *Pavona* in the U. S. National Museum is very large, and probably contains all the recognized living species. Some years ago I made a catalog of the species apparently referable to the genus, listed the types in the U. S. National Museum, and prepared a synoptic table for the determination of the species. As some of these notes may be of service to others, they are here published.

The following list shows the species assigned to *Pavonia* by Dana, the genera to which at present referred, and the types or original specimens of those in the U. S. National Museum, the latter being preceded by an asterisk:

Dana's names.	Genus to which at present referred.	Dana's names.	Genus to which at present referred.
*P. explanulata Dana (non Lam.).	Podobacia crustacea (Pallas).	*P. boletiformis (Dana, non Esper).	P. danai (M. Edw. and H.).
P crispa (Ehr.).	Haloseris.	*P. frondifera Lam.	Pavona.
*P. papyracea Dana.	Leptoseris.	*P. decussata Dana	Pavona.
P. elephantotus (Pallas).	Mycedium.	*P. lata Dana.	Pavona.
P. cactus (Forsk.).	Pavona.	*P. crassa Dana.	Pavona.
*P. prætorta Dana	Pavona.	P. siderea (Ell. and Sol.).	Siderastrea.
*P. formosa Dana.	Pavona.	P. latistella Dana.	Pavona?
*P. venusta Dana.	Pavona.	*P. clavus Dana.	Pavona.
*P. divaricata Lam.	Pavona.		

Verrill described *Pavona foliosa* and *P. complanata*, the types of which are in the U. S. National Museum.

An examination of a large series of *Pavona* at once shows that the species are divisible into two large groups, viz: (1) frondose or branching forms; (2) forms primarily incrusting, but which later may be massive. Group 1 is subdivisible into three subgroups: (1*a*) fronds with wide, flattish or gently curved sides, margins not greatly dissected; (1*b*) fronds crispate, summits divided into relatively narrow, more or less curled lobes; (1*c*) branches narrow, angular, keeled, and coalescent. These subgroups intergrade and must not be considered as fixed. The young of a species may belong to subgroup 1*b* and the fully developed colony to subgroup 1*a*; for instance, *P. danai* is based on a young colony, while *P. complanata* is the fully developed corallum. Without an adequate suite of specimens for comparison Verrill could not have known that the two belong together. Subgroup 1*c* is typified by *P. divaricata* Lam.

Special bibliographic references need be given only for the species described by Verrill, Brueggemann, and Ridley:

Pavonia varians Verrill, see p. 141 of this paper.

Pavonia foliosa Verrill, see Proc. Essex Inst., vol. 5, p. 44, Jan. 1867. This is a precise synonym of *P. frondifera* Lam., according to the specimens labeled by Dana. Distribution: Singapore; enormously abundant in the Philippines; Loo Choo Islands; Caroline Islands; Fiji Islands.

Pavonia complanata Verrill, *op. sup. cit.*, p. 45; for synonymy, description, and distribution, see p. 135 of this paper.
Pavonia gigantea Verrill, Proc. Bost. Soc. Nat. Hist., vol. 12, p. 395, 1869; Trans. Conn. Acad. Sci., vol. 1, p. 543, plate 9, figure 7, 1870; Pearl Islands, Panama.
Pavonia clivosa Verrill, Proc. Bost. Soc. Nat. Hist., vol. 12, p. 395, 1869; Trans. Conn. Acad. Sci., vol. 1, p. 544, plate 9, figure 8, 1870; Pearl Islands, Panama.
Lophoseris repens Brueggemann, see under *Pavona varians*, p. 138 of this paper.
Pavonia seriata Brueggemann, Mus. Godefroy, Jour., Heft 14, p. 206, 1879; Island of Ponapé.
Pavonia minor Brueggemann, *op. sup. cit.*, p. 207; Island of Ponapé.
Pavonia prismatica Brueggemann, *op. sup. cit.*, p. 207; Bonham Island.
Pavonia percarinata Ridley, Ann. Mag. Nat. Hist., 5th ser., vol. 11, p. 258, 1883; Galle, Ceylon.
Pavonia furcata Rehberg, Abhand. Naturwis. Ver. Hamburg, vol. 12, p. 25, plate 4, fig. 3, 1892; Island of Yap. The calices of this coral are bifacial; it is closely related to and is probably a synonym of *P. prætorta* Dana, although Rehberg says there are some keels.

Bassett-Smith, in his "Report on the Corals from Tizard and Macclesfield Banks, China Sea,"[1] describes and names *Pavonia pretiosa* and *P. ramosa*, which seem to me to belong to *Leptoseris* and to be very close to, if not identical with, *Leptoseris papyraca* (Dana). The same author refers to another specimen as *Pavonia* n. sp., which resembles a Hawaiian coral to which I applied the name *Leptoseris tubulifera*.

The names of species and variants represented in the U. S. National Museum are preceded by an asterisk in the following synopsis.

Synopsis of species of Pavona.

Corrallum frondose or ramose (calices bifacial).

Fronds flat-sided.
  Ambulacra flat, fronds thick, from 4 mm. to about 1 cm., except on the edge.
    Columella poorly developed or absent.
      With carinæ transverse to series.
        Distance between series 3 mm .... **P. decussata* Dana.
      Without carinæ.
        Calices in short or indistinct series, 2.5 to 4.5 mm. apart, principal septa prominent...... **P. lata* Dana.
    Columella well developed.
      Carinæ not greatly developed.
        Ambulacra wide, 3.5 to 5 mm. between series, series distinct from 15 to 30 mm. or more in length.......... **P. crassa* Dana.[2]
  Ambulacra flat, fronds maximum thickness about 7.5 mm.
    Columella a compressed style.
      Carinæ not greatly developed.
        Ambulacra 2 to 4 mm. wide, series fairly distinct.......... **P. danai* (M. Edw. and H.) / **P. complanata* Verrill. / **P. angularis* Klz.
  Ambulacra convex, septa crowded, fronds usually 3 or 4 mm. thick, near the base 6.5 mm. seems a maximum.
    Columella a small style, often compressed.
      Carinæ well developed.
        Distance between series 2 to 3 mm.; calices small.......... **P. frondifera* Lam. / **P. foliosa* Verrill.

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[1]Am. Mag. Nat. Hist., 6th ser. vol., 6, pp. 444, 445, 1890.

[2]The fronds of *P. crassa* are decidedly thicker and heavier than in the other species, and the inner ends of the septa are compactly joined together. The three varieties of *P. crassa* are discriminated as follows:

Plates wide, not intersecting.
  Edges acute .... var. *ascia*.
  Edges obtuse .... var. *obtusa*.
Plates wide, intersecting .... var. *loculata*.

Fronds crispate, summits divided into relatively narrow, more or less curled lobes.
Without carinæ.
Calices about 1 mm. in diameter.
Ambulacra flat or only slightly convex.
Septa subequal or only slightly alternating in size, except near the calicular fossæ; columella distinct.
Fronds with narrow (2 to 3 cm. wide) acute, thin, twisted summit lobes.......*P. prætorta* Dana
Fronds much wider (up to 12 cm.) and thicker, maximum thickness about 5 mm., thin on the edge, summit lobes 1 to 3 cm. wide... { **P. cactus* (Forsk.). **P. formosa* Dana. **P. knorri* (M. Edw. and H).
Fronds wider and calices more distant than in *P. cactus*...........*P. muelleri* (M. Edw. and H.).
Ambulacra flat.
Septa strongly alternating in size.
Folia intermediate in form between *P. prætorta* and *P. formosa*.............**P. venusta* (Dana).
With carinæ.
Ambulacra flat.
Series about 3 mm. apart, columella compressed in direction of series; septa strongly alternating in size.................................... { **P. danai* M. Edw. **P. laxa* Klz. **P. complanata* Verrill.
Branches narrow, angular, keeled, twisted, and coalescent.
Branches stout, 5–7 mm. thick, crowded, calices 2–3 mm. in diameter.................**P. divaricata* Lam.[1]
Branches prismatic, 3-sided, sharply triangular, looser than in *P. divaricata*...........*P. prismatica* Brueg.
Branches thin, foliaceous, many times bent, folded, and twisted, more numerous and more crowded than in *P. divaricata*..*P. minor* Brueg.
Externally like *P. divaricata*, except calices somewhat smaller, series more or less regular, separated by sharp or obtuse ambulacra...*P. seriata* Brueg.

Corallum massive.

Corallum forming clavate columns; calices in indistinct series, 3 mm. in diameter; walls below thick, solid, flat; septa 3 cycles or more; columella a compressed, thick knob....**P. clavus* Dana.[2]
Corallum forming thick plates, or of irregularly tuberose form; calices forming indistinct series; collines flat; calices 1.5 mm. in diameter; septa, 2 cycles; columella a single papilla...**P. duerdeni* Vaughan[2]
Corallum thin and spreading at the base, with knobs and columns in the center; calices 2–4 mm. in diameter, with flat or raised edges; 16–36 septa; columella well developed, a twisted rod or a flat-topped, thick, or a pointed style.............**P. maldivensis* (Gardiner).[2]
Corallum forming large, heavy masses; calices 2.5 mm. in diameter forming indistinct series; collines flat (5 mm. from summit to summit across fossa).......................**P. gigantea* Verrill.
Corallum forming rounded masses; calices without distinct serial arrangement; 1.5 to 2.5 mm. from wall to wall; septa, 2 cycles and some members of a third; columella a compressed tubercle..**P. clivosa* Verrill.

Corallum primarily incrusting, subsequently may become massive.

Upper surface hydnophoroid.
Columella often absent.
Valleys 3 to 4 mm. wide; with single series of calices; septa to calice about 24, 6 to 8 larger...**P. varians* Verrill.
Columella distinctly developed, papillary.
Diameter of calices 2 mm., septa 24..**P. repens* Brüg.[3]
Columella a small compressed spine.
Primarily incrusting, becoming massive; ambulacra 3 mm. across; ridges thin above, thick below; septa from 12 to 60, according to size of calices................**P. intermedia* Gardiner.[3]
Separated from *P. intermedia* by more completely circumscribed calices, wall thinner, no ridges between valleys..**P. calicifera* Gardiner.[3]
Corallum an attached lamina, without hydnophoroid protuberances.
Corallum an expanded, thin lamina, attached by a large area; upper surface subgibbous; calices 3 or 4 mm. in diameter. Some calices may be in series, separated by gently convex ambulacra. Columella a rather well-developed tubercle...........*P. explanulata* Lamarck.
Corallum an expanded, thin lamella which appears to be incrusting; upper surface flat or slightly gibbous; calices 2.5 to 3 mm. in diameter; columella rudimentary or absent. .*P. diffluens* Lamarck.
Corallum attached by the middle, forming a moderately thin and expanded lamella; upper surface slightly gibbous, rarely showing slightly elevated lines; calices in obscurely concentric lines; 5 mm. in diameter; columella rudimentary, papillary (fossil, Egypt)...*P ehrenbergi* (M. Edw. and H).[4]

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[1]Ortmann has described from Ceylon a coral under the name *Tichoseris angulosa*, which seems to belong in the *divaricata* group of *Pavona*. See Zool. Jahrb., Abtheil. für Syst., vol. 4, 1889, p. 515, pl. 14, fig. 1.

[2]These three supposed species are probably synonyms of *P. explanulata* Lam.

[3]Synonyms of *P. varians* Verrill.

[4]Von Marenzeller describes in Mitth. Naturhist. Mus. Wien, vol. 18, p. 126, fig. 4, 1901, a specimen referred by him to this species. He expressed the opinion that the species belongs to the genus *Coscinaræa* and not to *Pavona*.

Corallum an attached lamina, without hydnophoroid protuberances—continued.
Incrusting, nearly flat, calices nearly 0.5 inch (12.5 mm.) distant; interstices flat; columella?
Astræa diffluens Q. and G. (*non* Lamarck)........................ *P. latistella* Dana
Corallum incrusting at base, from which rise numerous cylindrical lobes; longitudinal sharp carinæ, 1 to 3 mm. tall; calices 1.5 to 2 mm. in diameter; septa 24, primaries and secondaries equal; columella a single pointed papilla, often absent or obscure.. *P. percarinata* Ridley.

Pavona cactus (Forskål).

Plate 56, figures 1, 1*a*, views of a frond from the original material of *Pavonia formosa* Dana.

1879. *Pavonia cactus* Klunzinger, Korall. Roth. Meer., pt. 3, p. 73, plate 9, fig. 2.
1906. *Pavonia cactus* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 90, plate 23, fig. 77.

Klunzinger and von Marenzeller have discussed the synonymy of this species, the type species of the genus, and I have made notes on it on pages 132 and 133 of the present paper. It is my belief that *Pavonia formosa* Dana and *Lophoseris knorri* Milne Edwards and Haime should be added to its synonymy.

Distribution.—Red Sea, thence eastward to Tahiti.

Pavona venusta Dana.

1846. *Pavonia venusta* Dana, U. S. Exploring Exped., Zooph., p. 326.

Recently I have been able to examine the type of this species in the Museum of the Boston Society of Natural History, and a few fragments have been presented to the U. S. National Museum. Dana's original description is excellent. The most nearly related species is *P. prætorta* Dana. In *P. venusta* there is a more conspicuous tendency for the septo-costæ to alternate in size and around the calicular margins the principal septa are more prominent than the intermediate septa. The elevation of the margins of the principal septa causes the calices to be slightly tumid around the edges. In the arrangement of its septo-costæ and principal septa it resembles *P. danai*, but the latter has much larger calices and coarser septo-costæ. From the information at present available to me, *P. venusta* appears to be a valid species.

Locality.—Dana gives no locality for the type, but it evidently came from the Indo-Pacific region.

Pavona danai (Milne Edwards and Haime).

Plate 55, figure 2, specimen from Cocos-Keeling Islands; plate 56, figures 2, 2*a*, type of the species.

1846. *Pavonia boletiformis* Dana, U. S. Expl. Exped., Zooph., p 327, plate 22, fig. 7 (*non* Lamarck).
1860. *Lophoseris danai* Milne Edwards, Hist. nat Corall., vol. 3, p. 71.
1867. *Pavonia complanata* Verrill, Proc. Essex Inst., vol. 5, p. 44.
1879. *Pavonia angularis* Klunzinger, Korall. Roth. Meer., pt. 3, p. 72, plate 9, fig. 7.
1879. *Pavonia laxa* Klunzinger, Korall. Roth. Meer., pt. 3, p. 73.
1907. *Pavonia decussata* Bedot, Madréporaires d'Amboine, p. 229, plate 35, figs. 180–182.

The following is a description of a specimen from Cocos-Keeling Islands:

Corallum frondose, fronds dissected, edges acute, thickened gradually toward the base, 8 mm. thick 4.1 mm. from the edge, forms compact, almost solid, laminæ curved or with flattish sides, not pronouncedly crispate; no carinæ on fragment here described.

Calices bifacial, arranged in definite, short, or indefinite rows roughly paralleling the growing edge. Distance between rows from 2.5 to 5 mm., usually about 3 mm.; distance between calicinal centers in the same row from 1.5 to 4 or 5 mm. Calicular cavities 1 to 1.5 mm. in diameter parallel to septo-costæ; from size stated up to about 3 mm. along line of rows. Depth about 1 mm. The intercalicular ambulacra are flat, crossed by alternately larger and smaller septo-costæ. About 5 (2 large and 3 small) septo-costæ to 1 mm., the larger ones about 0.5 mm. apart; sides of the larger densely beset with perpendicularly projecting, blunt-ended, fine granulations, between which the septal lamellæ show as white lines.

Septa in the subcircular calices 12 to 18 in number, alternately larger and smaller, the larger extending to the columella; in the elongate calices the number may reach 28 or 30. Within the calice the small septa are thin and do not reach the columella, while the

larger septa extend to the edge of the columella fossa, where their margins curve, drop perpendicularly, and fuse to the columella down in the calices.

Columella usually well developed as a solid, more or less compressed, stout, prominent style, but sometimes represented only by fused septal ends.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones says regarding this specimen:

"From east end of Pulu Tikus, on lagoon rocks, in water 1 fathom deep at low tide. This colony was the only one found, nor were any dead fragments picked up. The growth-form is as upright, thin laminæ, which were pale but bright. Color yellow. The colony was very conspicuous beneath the water. When dived for it was broken with great difficulty with a large hammer, as it was very hard."

As the original of Dana's *Pavonia boletiformis* (*non* Lamarck) = type of Milne Edwards's *Lophoseris danai* is in the U. S. National Museum, No. 135, it is figured (plate 56, figs 2, 2*a*), and the following notes are based on it:

The form and size of the type are sufficiently indicated by the figures. The fronds are dissected, the lobes curled or twisted, edges sharp, and carinæ are present. Calicinal series are only fairly obvious. There may be no calices within 10 mm. of the edge; farther down on the frond the distance from the calicinal centers in one series to those immediately above in the next series is from 2.5 to 3 mm.; the distance apart in the same series is from 2 to 2.5 mm. The ambulacra are crossed by strongly alternating septo-costæ, between which synapticulæ are obvious. The costal edges are sharp. From 6 to 9 prominent septo-costæ extend as septa to the columella axis, and alternate with much smaller septa. Near the edge of the frond the columella is absent or obscure, but in older calices it is well developed either as a flat calcareous plug or a lamellate style, compressed in the direction of the axis of the series.

A comparison of the description of Dana's type with that of the specimen from Cocos-Keeling shows that their characters are fundamentally similar, and that the principal difference consists in the apparent absence of carinæ on the latter. Dana's type is from Sulu Sea. Fortunately the U. S. National Museum possesses three good specimens and several fragments of *P. danai*, collected by J. B. Steere in Zamboanga, Philippines. These specimens (which are as nearly typical as can be imagined, one being almost a duplicate of the type, except that it is a more nearly perfect specimen) are young colonies; but one shows widening of the fronds by peripheral fusion of the lobes, and the carinæ become obscured with the thickening of the lower part of the frond. Two other specimens (one from Zamboanga and one from Mariveles, Luzon), which are older than the three colonies mentioned, show widening of the fronds with increasing size and nearly bridge the gap between the type of *P. danai* and the specimen from Cocos-Keeling Islands. The gap is completely bridged by an excellent specimen collected by Professor W. A. Bryan in the Caroline Islands.

Pavona laxa Klz.[1] is almost certainly this species. Klunzinger's *Pavonia angularis* is surely the same. Ridley referred to this coral as *Pavonia lata* Dana in his list of corals collected by Forbes in the Cocos-Keeling Islands.[2] The species is closely related to both *P. decussata* and *P. lata*, the principal difference being in the greater lobation of the plates. Therefore both Ridley and Bedot put the species in the proper place in the genus.

Distribution.—Red Sea; eastern Indian Ocean; Amboina (Bedot); Sulu Sea (Dana's type); southern Philippines (J. B. Steere); Luzon, Philippines (A. M. Reese); Caroline Islands (W. A. Bryan).

[1] Korall. Roth. Meer., pt. 3, p. 73, 1879.

[2] Forbes, H. O., A naturalist's wanderings in the Eastern Archipelago, p. 47, 1885.

Pavona maldivensis (Gardiner).

Plate 56, figures 3, 3*a*, 3*b*, specimen from Cocos-Keeling Islands.

1905. *Siderastrea maldivensis* Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., vol. 2, sup. 1, p. 935, plate 89, figs. 1–3.

In my memoir on the Hawaiian corals[1] I pointed out that *Siderastrea maldivensis* Gardiner does not belong to the genus *Siderastrea*, but groups with *Pavona clavus* Dana. Dr. Wood Jones collected two representative pieces of one colony in Cocos-Keeling, after having photographed the entire corallum. Two conditions of the calices as figured by Gardiner (*op. cit.*, plate 89, figs. 1 and 2) are represented. The columella in the lateral calices is often either strongly compressed and lamellate or a thickish twisted knob, as is shown in Gardiner's figure 2. A description of the species seems unnecessary.

Habitat and color, Cocos-Keeling Islands.—Dr. F. Wood Jones furnished the following notes:

"From lagoon edge of the barrier between Pulu Bras and Pulu Gangsa, where it is abundant; but the species is by no means generally distributed in the atoll and is on the whole rare. This is one of the palest corals, being nearly white while alive. The exposed portion of the zooid is sulphur yellow."

Distribution.—Maldives; Cocos-Keeling Islands.

Pavona varians (Verrill).

Plate 57, figures 1, 1*a*, 2, 2*a*, specimens from Murray Islands; figure 3, specimen from Cocos-Keeling Islands; figures 4, 4*a*, specimen from Fanning Island. Also plate 18, figure 44, of Dr. Mayer's article.

1864. *Pavonia varians* Verrill, Bull. Mus. Comp. Zool., vol. 1, p. 55.
1877. *Lophoseris repens* Brueggemann, Abhandl. nat. Vereins Bremen, vol. 5, p. 395, plate 7, fig. 1.
1879. *Pavonia repens* Klunzinger, Korall. Roth. Meer., pt. 3, p. 75, plate 9, fig. 3
1898. *Pavonia repens* Gardiner, Proc. Zool. Soc. London for 1898, p. 531, plate 44, fig. 2.
1898. *Pavonia intermedia* Gardiner, Proc. Zool. Soc. London for 1898, p. 531, plate 44, fig. 3.
1898. *Pavonia calicifera* Gardiner, Proc. Zool. Soc. London for 1898, p. 532, plate 44, fig. 4.
1905. *Pavonia repens* Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., vol. 2, sup. 1, p. 946, plate 90, figs. 9–11.
1907. *Pavona varians* Vaughan, U. S. Nat. Mus. Bull. 59, p. 135, plate 38, figs. 1, 1*a*
1910. *Pavonia* Wood Jones, Coral and Atolls, p. 74, text-fig. 12.

There are four specimens from Murray Island and two fragments from Cocos-Keeling Islands.

Gardiner has given so detailed a description of *P. repens* that here it is only necessary to add a few notes and make comparison with *P. varians* Verrill. The Murray Island specimens show individual non-serial corallites and serial corallites in the same colony. Therefore, as Gardiner pointed out in 1904, his *P. calicifera* and *P. intermedia* are synonyms of *P. repens* (Brueg.), and all, in my opinion, are synonyms of *P. varians* Verrill. The close affinities of *P. varians* and *P. repens* were noted by me in my memoir on the Hawaiian Madreporaria (p. 135). The crests in the former average greater in development, and are thicker, taller, and less acute; the calices are smaller, there are fewer septa, and the columella is often absent. The characters are fairly well shown on the figures I published of *P. varians* (*op. cit.*, plate 38, figs. 1, 1*a*), but the two intergrade. As *varians* is the older name, it is the proper one to apply to the species.

Stations, Murray Island.—Southeast reef, line I:

800 feet from shore, in water 11 inches deep; bottom hard, rocky.
830 feet from shore, in water 14 inches deep at lowest tide; hard bottom of living coral.

[1]U. S. Nat. Mus. Bull. 59, p. 136, 1907.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones says:

"Colony from Pulu Tikus barrier, western end. This is not at all a common coral in the atoll, and I found it in only one situation, *i. e.*, on the underside of the overhanging margins of deep barrier pools. It grows as an incrusting layer and rounds off the jagged edges of these pools. The color while alive varies from greenish brown to reddish brown; after death it turns green."

Distribution.—Red Sea (Brueggemann, Klunzinger); Maldives, Minikoi (Gardiner); Cocos-Keeling (Wood Jones); Funafuti and Rotuma (Gardiner); Fanning Island (Carl Elschner); Hawaiian Islands. In the Maldives it ranges in depth from low tide to 40 fathoms; range in depth in the Hawaiian Islands from surface to between 26 and 29 fathoms.

Genus CŒLOSERIS, new genus.

Type species: *Cœloseris mayeri* Vaughan, new sp.

Apparent generic characters: Corallum of massive growth-form. Calices polygonal, separated by simple, imperforate walls, which are secondarily thickened by vesicular endothecal dissepiments. Asexual reproduction by subequal fission. Septa imperforate, margins subentire, microscopically dentate. Synapticulæ present, but rare; when present they are near the wall. No columella.

This species is separable from the massive species of *Pavona* by the fewness of its synapticulæ and the absence of a columella.

Cœloseris mayeri, new genus and species.

Plate 58, figures 1, 1*a*, 1*b*, 2, 3*a*, 3*b*, specimens from Murray Island. Also plate 14, figure 18, of Dr. Mayer's article.

The following is a description of *Cœloseris mayeri*:

Corallum forms rounded, flattish, or columnar masses, up to 11 cm. in diameter by 10 cm. tall, and perhaps much larger.

Corallites polygonal, separated by simple, continuous, imperforate walls, which are secondarily thickened by steeply sloping dissepiments.

Calices from 4 mm. to 6 mm. in diameter, an occasional dividing calice 7 mm. long. Septa directly continuous between adjacent calices; in a small calice, about 22 distinct, 8 larger and longer, a few scarcely perceptible rudimentaries; in a large calice, 5.5 mm. in diameter, the number is 33, 10 larger than the others, 1 to 6 smaller septa between each pair of larger; arrangement therefore irregular. Upper septal edges slightly exsert, finely dentate, flattened or arched above; inner edges fall steeply into the narrow open axial cavity. Septal laminæ solid; faces with very minute granulations.

Two zones of dissepiments; those in the outer zone steeply inclined next the wall; those of the inner zone more nearly horizontal; the two zones separated by a vertical wall within the corallite wall proper. Distance between the dissepiments 0.5 to 0.75 mm. Synapticulæ rare, occasional near the wall.

There is no columella.

Asexual reproduction by subequal division.

In a thin section (see plate 39, figs. 3, 3*a*), the large septa continue from one calice to the next, but with a distinct euthecal line between their peripheral ends. The ends of the small septa abut against the eutheca and are not continuous across the wall; however, with increasing size the small septa overgrow the eutheca and then are confluent between calices.

The septal trabeculæ are from 0.05 to 0.10 mm. wide, *i. e.*, there would be from 10 to 20 teeth to 1 mm. on the septal edges. The growth segments of the septa are from about 0.6 to about 1 mm. wide.

Dissepiments are abundant; synapticulæ rare, occasional near the wall, but they are distinctly present and closely resemble those in *Agaricia agaricites*. The general resemblance to the microscopic characters of the last-mentioned species is striking.

Stations, Murray Island.—Southeast reef, line I:

400 feet from shore; water 4.5 to 5 inches deep.
600 feet from shore; water 15 inches deep; sandy bottom.
650 feet from shore; water 10 inches deep; sandy bottom.
800 feet from shore; water, 11 inches deep; hard, rocky bottom.
1,000–1,050 feet from shore; water about 14 inches deep at lowest tide; rocky bottom.
1,620–1,670 feet from shore (only specimen on the square); water 14 inches deep at lowest tide; hard, rocky bottom.

The specimen from the square 1,620–1,670 feet from shore is a small capuliform colony, 30 by 38 mm. in diameter; calices 3 to 4 mm. in diameter.

The generic determination of this coral has greatly perplexed me. The scarcity of synapticulæ, the simple intercorallite walls, and reproduction by fission at first inclined me to the opinion that it might be closely related to *Goniastrea*, but the confluent septa and the general aspect of the corallum are so similar to some of the massive species of *Pavona* that kinship with the latter genus seemed more probable. Microscopic study of thin sections discovered a few synapticulæ and revealed a skeletal structure similar to *Agaricia*. Dr. Mayer reports that in life the polyps were so similar to those of *Siderastrea* that he thought the species belonged to that genus. This observation accords with its reference to the Madreporaria Fungida.

In my paper on the Hawaiian Madreporaria[1] I have discussed the group of the species of *Pavona* typified by *P. clavus* (Dana), to which *Cœloseris* is closely related, except that it has no columella. *C. mayeri* somewhat resembles *Siderastrea spheroidalis* Ortmann,[2] but the latter has smaller calices and its columella is composed of 1 or 2 fine papillæ.

Distribution.—Murray Island; southern Philippines (J. B. Steere). The specimen collected by Mr. Steere is in all respects typical. Its surface is irregularly undulate; size, diameter 152 by 135 mm.; height 125 mm.

Genus AGARICIA Lamarck.

1801. *Agaricia* Lamarck, Syst. Anim. sans Vert., p. 373.
1905. *Agaricia* Vaughan, Science, n. s., vol. 21, p. 984.

Type species: *Madrepora undata* Ellis and Solander.

Agaricia ponderosa Gardiner.

1905. *Agaricia ponderosa* Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., vol 2, sup. 1, p. 937, plate 89, figs. 1, 2.

As I have identified an excellent and entirely typical specimen collected by Mr. J. B. Steere in the southern Philippines, it is mentioned because it extends the known geographic range of the species. I share with Professor Gardiner his hesitancy in referring the species to *Agaricia*, but am following his usage. Gardiner's description is excellent.

Distribution.—Minikoi (Gardiner); southern Philippines (J. B. Steere).

Genus PSAMMOCORA Dana.

1846. *Psammocora* Dana, U. S. Expl. Exped., Zooph., p. 34.

Type species: *Pavonia obtusangula* Lamarck.

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[1] U. S. Nat. Mus. Bull. 59, pp. 136, 137, 1907.

[2] Ortmann, Zool. Jahrb., Abth. für Syst., vol. 4, p. 496, plate 11, fig. 1, 1889; Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., vol. 2, sup. 1, p. 936, plate 89, fig. 4.

Psammocora gonagra Klunzinger.

Plate 59, figure 1, specimen from Murray Island. Also plate 18, figure 43, of Dr. Mayer's article.

1879. *Psammocora gonagra* Klunzinger, Korall. Roth. Meer., pt. 3, p. 80, plate 9, fig. 1.

Gardiner[1] refers this species to the synonymy of *P. digitata* Milne Edwards and Haime, but as he does not give the basis of his opinion, although he may be correct, I am using Klunzinger's name, of which I can be sure. Klunzinger's description applies so well that to write another seems superfluous. Dana's original specimen of *P. plicata* (not Lamarck) = type of *P. frondosa* Verrill, from Fiji Islands, is in the U. S. National Museum, No. 217. As the surface seems corroded, perhaps as the result of cleaning, I should not like to express a positive opinion, unless I had other specimens from the Fiji Islands for comparison, but I am inclined to believe it is the same as Klunzinger's *P. gonagra.*

Stations, Murray Island.—Southeast reef, line I:

545 feet from shore; water 11 inches deep at lowest tide; rocky bottom.
600 feet from shore; water 15 inches deep; bottom sandy.

Distribution.—Red Sea; although reported only by Gardiner, it must be widely distributed in the Indian Ocean; Murray Island.

Psammocora haimiana Milne Edwards and Haime.

Plate 59, figures 2, 2*a*, specimen from Cocos-Keeling Islands.

1852. *Psammocora haimiana* Milne Edwards and Haime, Ann. Sci. nat., 3d ser., Zool. vol. 16, p. 68.
1860. *Psammocora haimiana* Milne Edwards, Hist. nat. Corall., vol. 3, p. 221.
1879. *Psammocora haimeana* Klunzinger, Korall. Roth. Meer., pt. 3, p. 81, plate 9, fig. 5.
1905. *Psammocora haimeana* Gardiner, Fauna and Geogr. Maldive and Laccadive Arch., vol 2, sup. 1, p. 953.
1910. *Agaricia* Wood Jones, Coral and Atolls, p. 109, text-fig. 39.

The specimens from Cocos-Keeling Islands are so precisely like those figured by Klunzinger that no further description is needed.

Habitat and color, Cocos-Keeling Islands.—Dr. F. Wood Jones states: "Growth-form as flattened cakes; occurs as free masses in barrier pools and as incrustations on the dead bases of other corals in exposed places. Not abundant. Color while alive brownish or reddish brown."

Distribution.—Red Sea; Indian Ocean (Seychelles to Cocos-Keeling); Funafuti (Gardiner).

Psammocora sp.

Plate 59, figures 3, 3*a*, specimen from Cocos-Keeling Islands.

The following is a description of *Psammocora* sp. from Cocos-Keeling Islands:

Corallum incrusting, with an irregular, humpy, and hydnophoroid surface. Although the two small specimens show no branches, the form of one suggests that branches may be formed by the continued growth of some of the protuberances.

The dimensions of the specimens are: specimen No. 1, greater[2] diameter 49 mm., lesser[2] diameter 33 mm., total height 29 mm.;. specimen No. 2, greater diameter 38 mm., lesser[2] diameter 17 mm., total height 18 mm.

The distance between the summits of the ridges and hydnophoroid eminences ranges from about 1.5 to about 5 mm.; their height ranges up to 2 or 3 mm. The calices occur as clusters or as rows in the depressions, and on the eminences after a certain size has been attained. The cœnenchymal surface and the septal margins are roughened by tall, projecting trabecular ends, whose surfaces are closely granulate.

Calices fairly distinct or not distinct from the surrounding cœnenchyma; surficial, except a depressed central fossa; diameter about 1 mm.

[1]Fauna and Geogr. Maldive and Laccadive Arch., vol 2, sup. 1, p. 951.
[2]As the outline of the base is irregular these measurements are intended only roughly to indicate size.

Eight to ten septa reach the columella; about half of these bifurcate or trifurcate nearer the periphery of the calice. The outer ends are thicker than the inner ends. The interseptal loculi are distinct, about equal in width to the thickness of the septa. Usually two circles of septal denticles, the outer taller, wider, and thicker; on some septa a third denticle may be present. The denticles are radially compressed (not tangentially compressed as in *P. verrilli* Vaughan). Their sides minutely granulate. The outer septal ends continuous with the cœnenchyma.

The cœnenchyma is composed of radial elements connecting with the septa and concentric synapticulæ. The interspaces in the reticulum are distinct; but in sections parallel to the flat surfaces the radial structures are fairly compact. The roughness of the surface has been described.

The columellar tangle is variable in development; it is lax or fairly compact, composed of the fused inner ends of the long septa and a more or less complete ring of synapticulæ. Usually there is a distinct small, compressed, granulate columellar tubercle.

Habitat and color.—Dr. F. Wood Jones states: "Grows upon the sand flats; not common. Purple while living."

Although these specimens do not accord with any of the species known to me, it seems hazardous to propose a name, as the colonies appear immature. They suggest the early stages of a branching form, and may belong to *P. obtusangula* (Lamarck). They are not *P. frondosa* Verrill, *P. gonagra* Klunzinger, or *P. contigua* (Esper); nor are they *P. verrilli* Vaughan, an incrusting form found in the Hawaiian Islands. The latter may ultimately prove to be a young stage of *P. contigua*, as the calicular and cœnenchymal characters of the two are essentially the same.

Psammocora profundacella Gardiner.

Plate 59, figures 4, 4*a*, specimen from Fanning Island.

1898. *Psammocora profundacella* Gardiner, Proc. Zool. Soc. London for 1898, p. 537, plate 45, fig. 3.

Mr. Elschner collected at Fanning Island a subspheroidal specimen 72 to 74 mm. in diameter and 50 mm. thick. Living polyps had covered all the surface, and when collected they were dead over an area on the lower surface only 36 mm. in diameter. As Gardiner's description is so good, a new one seems unnecessary, but two figures are given, plate 59, figures 4, 4*a*.

Distribution.—Funafuti (Gardiner); Fanning Island (Elschner).

GENUS NOT REFERRED TO A FAMILY.

Genus DIPLOASTREA Matthai.

1914. *Diploastrea* Matthai, Trans. Linn. Soc. London, ser. 2, Zool., vol. 17, p. 72.

Type species: *Astrea heliopora* Lamarck.

This a fungid coral, as it possesses well-developed synapticulæ and there are large, irregularly distributed perforations in the septa. The septo-costæ are either confluent, but notched at the corallite boundaries, or their outer ends alternate in position. There is no definite intercorallite wall, it being represented by a discontinuous series of peripherally placed synapticulæ. Matthai's figures show both the synapticulæ and the perforate septa. Ultimately *Diploastrea* may become a synonym of *Cyathomorpha* Reuss.

Diploastrea is one of the most important genera of Oligocene corals in the southeastern United States and in the West Indies. *Astræa crassolamellata* Duncan,[1] from Antigua, belongs to it. It is also found in the lowest horizon at Crocus Bay, Anguilla; in Cuba at numerous localities; along Flint River near Bainbridge, Georgia; and in eastern Mexico.

[1]Quart. Jour. Geol. Soc. London, vol. 19, p. 412, plate 13, figs. 1–7, 1863.

Diploastrea heliopora (Lamarck).

Plate 59, figures 5, 5*a*, Dana's type of *Astræa patula*.

1816. *Astrea heliopora* Lamarck, Hist. nat. Anim. sans Vert., p. 265.
1846. *Astræa glaucopsis* Dana, U. S. Expl. Exped., Zooph., p. 208, plate 10, figs. 2*a*, 2*b*.
1846. *Astræa patula* Dana, U. S. Expl. Exped., Zooph., p. 209, plate 10, figs. 14, 14*a*–14*e*.
1904. *Orbicella minikoiensis* Gardiner, Fauna and Geog. Maldive and Laccadive Arch., vol. 2, p. 774, plate 63, fig. 35.
1907. *Orbicella minikoiensis* Vaughan, Proc. U. S. Nat. Mus., vol. 32, p. 252.
1914. *Diploastrea heliopora* Matthai, Trans. Linn. Soc. London, 2d ser., Zool., vol. 17, p. 72, plate 20, figs. 7, 8; plate 34, fig. 9.

Dana's type of *Astræa* (*Orbicella*) *glaucopsis* is No. 3, U. S. National Museum, and his type of *Astræa* (*Orbicella*) *patula* is No. 16, U. S. National Museum. The type of the former, although a broken segment of a large head, is so completely typical for *D. heliopora* that no notes on it are necessary. Dana's type of the latter is represented by plate 59, figures 5, 5*a*. Mr. Matthai directed my attention to this being a synonym of *D. heliopora*. It differs from typical specimens of the species by having less exsert septal margins and somewhat thicker septa.

Distribution.—French Somaliland; Minikoi; New Britain; Fiji Islands. This is a widely distributed Indo-Pacific species. Matthai apparently translated Lamarck's "Mer australes" as Australia; but Lamarck probably meant "South Seas." I know of no trustworthy record of the species from Australia, but as it has been found in the Indian Ocean to the west and in the Pacific Ocean to the east of Australia, it almost certainly occurs there.

MADREPORARIA PERFORATA.

Family EUPSAMMIIDÆ Milne Edwards and Haime.

Genus DENDROPHYLLIA de Blainville.

1830. *Dendrophyllia* de Blainville, Dict. Sci. nat., vol. 60, p. 319.
1850. *Dendrophyllia* Milne Edwards and Haime, Brit. foss. Cor., p. liii.
1860. *Dendrophyllia* Milne Edwards, Hist. nat. Corall., vol. 3, p. 112.

Type species: *Madrepora ramea* Linnæus.

This, the first species referred to the genus by de Blainville, was designated as the type species by Milne Edwards and Haime in 1850.

Dendrophyllia nigrescens Dana.

Plate 60, figures 1, 1*a*, specimen from Murray Island.

1846. *Dendrophyllia nigrescens* Dana, U. S. Expl. Exped., Zooph., p. 387, pl. 30 [should be 27], figs. 1, 1*a*–1*f*.
1860. *Cœnopsammia nigrescens* Milne Edwards, Hist. nat. Corall., vol. 3, p. 129.

The specimens collected by Dr. Mayer are about typical. This species is represented in the U. S. National Museum by purchased specimens from "Australia." It may form colonies 2 or 3 feet in height, the basal part becoming correspondingly thickened.

Station, Murray Island.—Northwest side, depth 18 fathoms, rocky bottom.

Distribution.—Red Sea; Seychelles (Milne Edwards); Murray Island; Fiji Islands (Dana's types); southern Philippines (Steere, U. S. Nat. Mus. collection).

Dendrophyllia willeyi (Gardiner).

Plate 60, figures 4, 4*a*, specimen from Cocos-Keeling Islands.

1899 *Cœnopsammia willeyi* Gardiner, Willey's Zool. Results, pt. 4, p. 359, plate 34.
1910. *Cœnopsammia willeyi* Wood Jones, Coral and Atolls, p. 85, text-fig. 22.

As Gardiner has given a good description of this species, only a few annotations need be made here. The maximum diameter of the large calices is 10 mm.

Frequently tabuliform floors form across the bottoms of deep calices below the level of the columella, but in some of the calices on the edge of the colony the floors curve upward into the interseptal loculi above the columella level.

Habitat, etc., Cocos-Keeling Islands.—The notes of Dr. F. Wood Jones state as follows:

"Limited to small colonies; local in distribution; found most commonly at the east end of Pulu Tikus, never at the west end. Lives only on the barrier and constantly grows on the underside of 'negro heads' and large boulders, or in chinks in compound rocks. It nearly always grows mouth downward and away from the light. It expands only in the dark. When the colony consists of one or two polyps it is colored bright chrome-yellow to orange; when older it is brilliant vermillion; at all times it has an iridescence resembling solutions of eosin."

Distribution.—Cocos-Keeling Islands; Lifu, Loyalty group; Fanning Island (C. Elschner).

Cœnopsammia manni Verrill, a closely related species found in the Hawaiian Islands, is vermillion while alive; *C. ehrenbergiana* M. Edw. and H. and *C. coccinea* (Ehr.), from the Red Sea, according to Klunzinger, and *C. aurea* (Q. and G.) from Australia, are also reddish in color. It seems probable that *C. willeyi* may be a synonym of *C. aurea* (Q. and G.).

Dendrophyllia manni (Verrill).

1866. *Cœnopsammia manni* Verrill, Proc. Essex Inst., vol. 3, p. 30.
1907. *Dendrophyllia manni* Vaughan, U. S Nat. Mus. Bull. 59, p. 156, plate 46, figs. 6, 6*a*, 7, 7*a*.

Mr. Elschner obtained at Fanning Island a colony which was black while alive, thereby differing from typical *D. manni.* There are on the same corallum both short and exsert corallites. The columella is well developed, spongy, in some instances composed of curled flakes. There may or may not be a faintly developed crest along the columella summit. The columella is better developed than in the specimens I figured from Kaneohe, Oahu (*op. cit.*, plate 46, figs. 7, 7*a*), but about the same as in Verrill's cotype (*op. cit.*, plate 46, figs. 6, 6*a*); it is more vesicular than in *D. willeyi* and the crest on its upper surface is less distinct. The specimen has considerable resemblance to *D. coccinea* Dana = *D. danæ* Verrill,[1] but its columella is coarser in texture than that of the latter. I should not be surprised if large suites of specimens showed that *D. aurea, D. danæ, D. manni*, and *D. willeyi* were variants of the same species.

Distribution.—Hawaiian Islands; Fanning Island (C. Elschner).

Dendrophyllia diaphana Dana.

Plate 60, figures 2, 2*a*, Dana's type; figures 3, 3*a*, specimen from Cocos-Keeling Islands.

1846. *Dendrophyllia diaphana* Dana, U. S. Expl. Exped., Zooph., p. 389, plate 30 [27], fig. 3.

A description of *Dendrophyllia diaphana* from Cocos-Keeling Islands is as follows:

Corallum composed of small clusters of corallites rising from a narrow base. Dimensions of largest colony: height, 35 mm.; greater diameter in horizontal plane, 38 mm.; lesser diameter in horizontal plane, about 32 mm. The daughter corallites mostly bud from near the base of the parent and diverge upward, but there is occasional gemmation from just below the calicular margin. The extension of the edge zone below the calicular edge seems largely determined by environmental conditions; when conditions are favorable it may be as much as 25 mm.; when unfavorable it may be only 2.5 mm. There is no well-developed epitheca, but a few epithecal threads may mark the lower margin of the edge zone.

[1] *Dendrophyllia coccinea*, Dana, U. S. Expl. Exped., Zooph., p. 388, plate 27, fig. 4 (*Oculina coccinea* Ehr.) = *Dendrophyllia danæ* Verrill, in Dana's Corals and Coral Islands, p. 384.

The corallites are relatively tall and normally increase in diameter with upward growth. Height of free portion from 6 to 10 mm. On the periphery of the corallum corallites may be free for 15 mm. Diameters of healthy adult calices: greater, 9 to 10 mm.; lesser, 8.5 to 9 mm. Depth, about 7 mm. Stunted calices may be only 6 mm. in diameter and 4 mm. deep. Greater basal diameter of a healthy corallite, 6.5 to 9 mm.

Wall thin, fragile, and perforate near upper edge, perforations decreasing toward the base but represented by pits with translucent bottoms. Low, equal, somewhat sinuous costæ correspond to all septa. Costal profiles flattish or slightly acute, narrow intercostal furrows perforated as has been stated. Minute granulations distributed over the costal surfaces, not confined to the costal summits.

Septa thin, 4 complete cycles in normal adult calices. Primaries the largest with corresponding slight elevations on the calicular margins. Their margins are entire, slope inward through a distance of about one-third the diameter of the calice and then fall perpendicularly to the outer edge of the columella. The secondaries have free portions about two-thirds as wide as the primaries; and by a curve low down in the calice join the columella; The tertiaries are very thin and are usually narrow, sometimes one reaches the columella, but oftener the dendrophylliid septal grouping is indicated. The quaternaries may be rudimentary, represented by low spines, or those next a primary may be considerably developed and fuse to the nearest secondary, thus initiating the arrangement of septa usual in the family. Septal faces with small granulations. Interseptal loculi open and deep.

Columella compressed; usually, but not invariably, well developed; composed of curled trabeculæ; somewhat protuberant in the bottom of the calice. Its length about one-third that of the calice; its width one-sixth to one-fifth that of the calice.

Habitat and color, Cocos-Keeling Islands.—Dr. F. Wood Jones supplies the following notes:

"The color is the brown-black of India ink and when living has a greenish fluorescence about the disk. Black when dead. Very similar in habit to *C. willeyi* and found in company with it. Always in very small masses, 2 or 3 individuals, and I have never seen a growth so large as the specimen of *C. willeyi*. By no means abundant. Lives in the darkest holes and is inactive in the light. I have never picked up a wave-cast specimen."

Dana's type is No. 180 in the U. S. National Museum. The bottom of the calice in the type is narrower and the columella less developed than is usual in the Cocos-Keeling specimens, but there is complete overlapping. The base of this species does not spread as in *C. willeyi*. The nearest related form known to me is *C. manni* Verrill, from the Hawaiian Islands, which has much larger calices, and while alive normally has vermillion-red polyps.

Distribution.—Singapore (Dana's type); Cocos-Keeling Islands.

Family ACROPORIDÆ Verril.

Genus ASTREOPORA de Blainville.

1830. *Astreopora* de Blainville, Dist. Sci. nat., vol. 60, p. 348.
1849. *Astreopora* Milne Edwards and Haime, Acad. Sci., Comptes rend., p. 258.
1896. *Astræopora* Bernard, Cat. Gen. Astræopora, Cat. Madreporaria Brit. Mus., vol 2, pp. 77-99.

Type species: *Astrea myriopthalma* Lamarck.

Bernard records the following species from Australia:

Species of Astreopora reported by Bernard from Australia.

Name.	Locality.	Notes.
A. hirsuta Bernard.....	Rocky Island..................	Almost certainly *A. myriophthalma*.
A. ocellata Bernard....	Warrior Islands; Baudin Islands..	*A. ovalis* and *A. kenti* are synonyms of this.
A. punctifera (Lam.)....	Great Barrier Reef.	
A. kenti Bernard.......	King's Sound, W. Australia......	Synonym of *A. ocellata*.
A. profunda Verrill.....	Great Barrier Reef; ?Banda.	

The notes suggest that the list of species of *Astreopora* from Australia should be *A. myriophthalma* (Lamarck), *A. ocellata* Bernard, *A. punctifera* (Lamarck), and *A. profunda* Verrill.

Astreopora myriophthalma (Lamarck).

Plate 60, figures 5, 5*a*, specimen from Cocos-Keeling Islands.

1879. *Astreopora myriophthalma* Klunzinger, Korall. Roth. Meer., pt. 2, p. 52, plate 5, fig. 31.
1896. *Astræopora myriophthalma* Bernard, Cat. Gen. Astræopora, p. 87, plates 25, 26; plate 33, fig. 9.
1896. *Astræopora ehrenbergii* Bernard, Cat. Gen. Astræopora, p. 92, plate 33, fig. 15.

The following is a description of a specimen of *Astreopora myriophthalma* from Cocos-Keeling Islands:

Corallum pulvinate; horizontal diameter about 85 mm.; thickness, 51 mm.

Calices, diameter of largest 2.25 mm., usual range from 1.5 to 2 mm., 1.5 mm. a frequent measure, average size therefore small. Distance apart 2 to 4 mm. Margins elevated, often 2 mm. or more, up to at least 3 mm., usually of fairly uniform height. The walls are perforate membranes. Outside the walls the corallites are swollen toward the base of the projecting part, the slope from one calice meeting that from its neighbor. Costæ thin, prominent, correspond to septa of the first and second cycles and an occasional tertiary. They are jaggedly dentate, the dentations, which end in spiniform teeth, increase in height from the calicular margin downward. Small calices, down to 1 mm. in diameter, between the larger.

Septa, primaries narrow above, wide below, where their edges often meet and fuse by spiniform processes, but never form a well-developed columella; secondaries usually present but always narrow; very rarely may a rudimentary tertiary be distinguished.

Tabulæ irregularly developed, thin, 1 to 3 mm. apart.

Cœnenchyma forms fairly continuous but perforate platforms; successive floors fairly definite in longitudinal sections; over its surface tall, hirsute spinules, which usually end in single, occasionally in double, rarely in fimbriate points.

Habitat, etc., Cocos Keeling Islands.—"Barrier pools; color of living colonies yellow or purple" (F. Wood Jones).

Another specimen has a denser corallum, the costæ and cœnenchymal spines are lower, and the primary septa do not meet in the axis, but the scheme of the relations of the structural elements is the same as in the specimen described in detail.

Bernard described two species of *Astreopora*, in which there are prominent, roughly dentate costæ around the calices, viz, *A. myriophthalma* (Lamarck) and *A. hirsuta* Bernard, and apparently *A. ehrenbergii* Bernard, which is based on Klunzinger's *A. myriophthalma*, is similar in this character. There is no reasonable doubt that the specimens from Cocos-Keeling are both the *A. myriopthalma* of Bernard and Klunzinger. The specimen with the denser corallum, etc., completely satisfies the requirements of Klunzinger's description and figure; while, except in growth-form, the characters accord with Bernard's description and figures. Bernard attaches much importance to whether the growth-form is explanate, pulvinate, or globular. These distinctions are not of fundamental value. *Siderastrea radians* (Pallas) exhibits in the same species all three growth-forms; *Siderastrea siderea* (Ell. and Sol.) is either explanate or pulvinate, as also is *Porites astreoides* Lam. Instances of explanate, pulvinate, and hemispherical growth-form in the same species might be multiplied almost indefinitely. In fact, the generalization may be made that any coral which under certain conditions has a hemispherical growth-form will under other, but proper, conditions produce a flattish, a slightly convex, or a pulvinate colony.

Distribution.—From Red Sea and the western Indian Ocean to Fanning Island. Mr. C. Elschner collected a good specimen, now in the U. S. National Museum, at the last-mentioned locality.

Astreopora ocellata Bernard.

Plate 17, figures 36, 37, of Dr. Mayer's article.

1895. *Astræopora ocellata* Bernard, Cat. Gen. Astræopora, p. 95, plate 29; plate 33, fig. 16.
1895. *Astræopora ovalis* Bernard, Cat. Gen, Astræopora, p. 97, plate 30; plate 33, fig. 17.
1896. *Astræopora kenti* Bernard, Cat. Gen. Astræopora, p. 97, plate 30; plate 33, fig. 19.

The following are descriptions of specimens of *Astreopora ocellata* from Murray Island:

Specimen No. 1.—Corallum small, irregularly hemispherical; diameters, 44 by 57 mm.; height, 41 mm. Attached by the base, on which epitheca is present.

Calices very deep; of two kinds, larger with prominent margins, smaller with low margins, the latter, however, by growth become prominent. Furthermore, the calices on one side are uniformly smaller than on the other. Diameter of the large calices from 2.5 to 3 mm.; margins exsert about 1 mm., frequently higher on one side than on the other. Small calices appear in the bottoms of the depressions in the interspaces between the large; diameter ranges up from 1.5 mm. to the size of the large calices. Distance between calices from 1.5 to 3 mm., usually about 2 mm. On the side of the corallum, where the calices are smaller, the diameter of largest is about 2 mm., of the smallest 1 mm.; distance apart, up to 3 mm.

Septa in large calices, the 6 primaries, sometimes 7 or 8 septa, are more prominent than the others. These are narrow above; deep down in the calice they may loosely fuse by their inner edges, but usually they appear not to fuse. Smaller secondaries are constantly present as ridges between the primaries, and frequently the third cycle is represented in a number of half systems by rudimentary septa, but this cycle is rarely or never complete. In the smallest calices the septa may not be distinct. On the side of the corallum where the calices are smaller, the first and second cycles are well developed and there are a few small tertiaries. There is no distinct columella; corallite tubes crossed by thin tabulæ, about 1 mm. apart.

Around the calices are fairly definite roughly spinulose costæ. The cœnenchyma seem to form successive perforate platforms which are supported on the spines or through which the ascending trabeculæ project as spines.

Specimen No. 2.—Upper surface not so steeply arched as in No. 1, more distinctly of the pulvinate growth-form. Larger calices average about 2 mm. in diameter. Distance apart of calices 1 to 2 mm. Usually only 2 cycles of septa, occasional rudimentary tertiaries. This specimen has all the essential structure of No. 1, its difference consisting in less luxuriant growth than on the top and the side of No. 1, where the calices are larger.

Stations, Murray Island:

Specimen No. 1, southeast reef flat, line I, 1,200–1,250 feet from shore; water 16 inches deep at lowest tide; bottom hard, of broken coral.

Specimen No. 2, southeast reef flat, line I, 1,620–1,670 feet from shore; water 14 to 16 inches deep at low tide; hard, rocky bottom.

I have referred to the same species three of the forms of *Astreopora* to which Bernard assigned specific names. All are characterized by having the corallites somewhat protuberant and swollen around the base of the projecting part, by having definite or fairly definite echinulate costæ outside the corallite walls, by septa which are narrow above, and the primaries, although they widen down in the calices, do not form a columella. The differences pointed out by Bernard may all be accounted for by vegetative variation. Specimen No. 1 may be referred indifferently to *A. ocellata* or *A. ovalis*, while specimen No. 2 might be referred to *A. kenti*.

Distribution.—At present known only from the Great Barrier Reef and Baudin Island.

Genus TURBINARIA Oken.

1815. *Turbinaria* Oken, Lehrb. Naturg., Th. 3., Abth. 1, p. 67.

Type species: *Madrepora crater* Pallas.

The species of *Turbinaria* reported from Australia by Bernard are listed on the following page. How many of the 27 reputed species should be recognized as valid can only be determined by a critical revision of Bernard's original specimens,

[1]Brit. Mus. (Nat. Hist.), Cat. Madreporaria, vol. 2, Turbinaria, pp. 1–75, 1896.

perhaps in the light of larger collections. Although Bernard did excellent work on the morphology of the coral skeleton (in fact his work is of fundamental importance), he seems never to have been able to group his specimens into what is understood by systematists as species. His species are merely morphologic variations, and many of the names he proposed will not persist in the literature.

Species of Turbinaria reported by Bernard from Australia.

Name.	Localities.
T. crater (Pallas)	King's Sound and Roebuck Bay, West Australia; Thursday Island; Great Barrier Reef.
T. danæ Bernard	Malay Seas; west Singapore; Formosa; Australia.
T. edwardsi Bernard	King's Sound and Roebuck Bay, West Australia.
T. plicata Bernard	Roebuck Bay, West Australia.
T. undata Bernard	King's Sound, West Australia.
T. speciosa Bernard	Port Denison.
T. aurantiaca Bernard	Port Denison, Great Barrier Reef, and Torres Straits.
T. æqualis Bernard	Wednesday Island, Torres Strait; Great Barrier Reef; Basset-Smith Shoal, Holothuria Reef.
T. pustulosa Bernard	Port Denison, Great Barrier Reef; Gulf of Carpentaria.
T. nidifera Bernard	Great Barrier Reef.
T. abnormalis Bernard	Great Barrier Reef.
T. pocilliformis Bernard	Northwest Australia.
T. peltata (Esper)	King's Sound, Northwest Australia; Roebuck Bay, West Australia; Shark's Bay; Somerset, Cape York; Wide Bay, Great Barrier Reef; Port Denison; Singapore; Malay Seas; Mauritius.
T. patula Dana	Sumatra; Wednesday Island, Torres Straits; Holothuria Bank; Gulf of Carpentaria; Great Barrier Reef.
T. orbicularis Bernard	King's Sound, West Australia; Somerset Shore, Cape York.
T. radicalis Bernard	Great Barrier Reef.
T. agaricia Bernard	Torres Straits (west).
T. magna Bernard	Shark's Bay; Wednesday Island, Torres Straits; Green Island, Great Barrier Reef; Port Denison.
T. robusta Bernard	Port Denison, Queensland; Torres Straits (west); Gulf of Carpentaria; Great Barrier Reef; North Australia; Port Essington; Northeast Australia.
T. sinensis Verrill	Formosa; Rocky Island, Great Barrier Reef.
T. venusta Bernard	Great Barrier Reef.
T. mesenterina Bernard	Island of Rodriguez; Great Barrier Reef.
T. lichenoides Bernard	Great Barrier Reef; Townsend, Great Barrier Reef.
T. reptans Bernard	Torres Straits.
T. reniformis Bernard	Palm Islands, Great Barrier Reef.
T. crassa Bernard	Great Barrier Reef.
T. elegans Bernard	Tongatabu; Rocky Island, Great Barrier Reef.

Dr. Mayer collected no specimens of *Turbinaria* at Murray Island, nor did Dr. Wood Jones collect any in the Cocos-Keeling group. There are in the U. S. National Museum one good specimen of *T. crater* and a suite of three specimens of *T. peltata* from Torres Straits. As Bernard has described these species in detail and published illustrations of them, they need only be mentioned here.

Genus MONTIPORA Quoy and Gaimard.

1833. *Montipora* Quoy and Gaimard, Voy. de l' *Astrolabe*, Zool., vol. 4, p. 247.
1847. *Montipora* Bernard, Brit. Mus. (Nat. Hist.), Cat. Madreporaria, vol. 3, the genus Montipora, pp. 1–166, 177–184.

Type species: *Montipora verrucosa* Quoy and Gaimard (*non* Lamarck) = *Montipora foveolata* (Dana). As Dana's type of *Manopora foveolata* appears not to be in the U. S. National Museum, I can not redescribe and figure it, as I had desired.

Bernard records the following species of *Montipora* from Australia:

Species of Montipora reported by Bernard from Australia.

Name.	Localities.
Glabrous Montiporæ.	
Montipora punctata Bernard	Albany Passage, Great Barrier Reef.
auricularis Bernard	Thursday Island; Great Barrier Reef.
exserta Quelch	Wednesday Island, Torres Straits.
mollis Bernard	Palm and Warrior Islands, Great Barrier Reef.
fruticosa Bernard	Warrior Island, and unspecified localities on the Great Barrier Reef.
nana Bernard	Port Molle, Queensland, and northeast coast, Australia.
Glabro-foveolate Montiporæ.	
Montipora rotunda Bernard	Palm Island, Great Barrier Reef.
spatula Bernard	Warrior Reef, Great Barrier Reef.
Foveolate Montiporæ.	
Montipora libera Bernard	Torres Straits.
turgescens Bernard	Green, Capricorn, and Rocky Islands, Great Barrier Reef; Northwest Australia.
socialis Bernard	Capricorn Islands, Great Barrier Reef.
caliculata (Dana)	Torres Straits; Warrior and Rocky Islands, Great Barrier Reef.
multiformis Bernard	Houtman's Abrolhos; King's Sound, West Australia.
gaimardi Bernard	?Australia.
indentata Bernard	Great Barrier Reef.
Papillate Montiporæ.	
Montipora spumosa (Lamarck)	Rocky Island, Great Barrier Reef; Lacépède Island, Northwest Australia.
flammans Bernard	Port Darwin, Great Barrier Reef.
papillosa (Lamarck)	Torres Straits.
australiensis Bernard	Houtman's Abrolhos, West Australia.
danæ Milne Edwards and Haime.	Port Denison.
verrucosa (Lamarck)	Palm Island Albany Passage, Great Barrier Reef, other localities not specified; Torres Straits.
var. α	Palm Island, Great Barrier Reef.
var. β	Thursday Island; Great Barrier Reef.
var. γ	Great Barrier Reef.
ambigua Bernard	Thursday Island; Great Barrier Reef.
sinensis Bernard	Palm Island, Great Barrier Reef.
Tuberculate Montiporæ.	
Montipora variabilis Bernard	Warrior Island and ?Albany Passage, Great Barrier Reef.
mammillata Bernard	Capricorn Island, Great Barrier Reef.
stellata Bernard	Rocky Island and Cleveland Bay, Great Barrier Reef.
lichen (Dana)	Thursday Island; Great Barrier Reef; Adolphus Island.
scutata Bernard	Thursday Island; Warrior Island and Albany Passage, Great Barrier Reef.
granulata Bernard	Torres Straits.
æqui-tuberculata Bernard	Thursday Island; Albany Passage, Great Barrier Reef.
informis Bernard	Murray Island.
crassi-tuberculata Bernard	Houtman's Abrolhos, West Australia.
effusa (Dana)	Rocky and Palm Islands, Great Barrier Reef.
frondens Bernard	Palm Island, Great Barrier Reef.
trabeculata Bernard	Townsville, Great Barrier Reef.
fimbriata Bernard	Warrior Island, Great Barrier Reef.
striata Bernard	Houtman's Abrolhos, West Australia.
circinata Bernard	Palm Islands, Great Barrier Reef.
plicata Bernard	Torres Straits.
bifrontalis Bernard	Palm Island, Great Barrier Reef.

How many of these names applied to morphologic variations will be accepted in systematic nomenclature can only be decided after a complete revision of the genus. On page 151 I suggest that Bernard's *M. divaricata*, *M. compressa* (*non* Dana), and *M. fruticosa* be referred to the synonymy of *M. ramosa* Bernard.

Glabrous Montiporæ.

Montipora levis Quelch.

Plate 61, figures 1, 1*a*, specimen from Cocos-Keeling Islands.

1886. *Montipora levis* Quelch, Reef Corals, *Challenger* Reports, p. 172, plate 8, figs. 2, 2*a*.
1897. *Montipora levis* Bernard, Cat. Montipora, p. 41, plate 31, fig. 19.

There appears to be no need to repeat the descriptions of Quelch and Bernard. The species is not closely related to *M. palmata* Dana, as Quelch supposed, for the latter belongs to the tuberculate Montiporæ.

Habitat, Cocos-Keeling Islands.—"In the lagoon and lagoon inlets; particularly abundant upon the lagoon margin of the barrier flats stretching between Pulu Tikus and Pulu Gangsa. A shallow-water species, which lives where the water is not rough but is moving." (F. Wood Jones.)

Distribution.—Cocos-Keeling; Banda; Fiji Islands.

Montipora tortuosa (Dana).

Plate 61, figures 2, 2*a*, Dana's type; figures 3, 3*a*, specimen from Cocos-Keeling Islands.

1846. *Manopora tortuosa* Dana, U. S. Expl. Exped., Zooph., p. 509, plate 48, fig. 2.
1897. *Montipora tortuosa* Bernard, Cat. Montipora, p. 48.

In the collection of the U. S. Exploring Expedition corals in the U. S. National Museum, No. 310 is *Manopora tortuosa* Dana and No. 312 *Manopora digitata* Dana. They seem to be Dana's types. The two are so nearly related that it is doubtful if they represent different species, a relationship of which Dana was aware. *M. tortuosa* has longer branches, the outer cœnenchymal surface is flaky, and the surface granulations are finer than in *M. digitata.* Each species usually has six distinct primary septa; the second cycle may be, but usually is not, completely represented by much smaller septa in *M. tortuosa*, while it seems to be nowhere complete in *M. digitata.*

The specimen from Cocos-Keeling is typical *M. tortuosa*, except that the calices average smaller, diameter 0.3 to 0.5 mm.; distance apart, usually 1 to 1.5 mm., near branch tips in places 0.5 mm. Second cycle of septa rarely complete.

Habitat, etc., Cocos-Keeling Islands.—Dr. F. Wood Jones states:

"Specimens brought up on lines from depths of 5 or 6 fathoms in the lagoon. The branches are almost colorless, and are of great length, in many instances being 2 feet long and without any indication of lateral branch formation. The zooid is pale yellow. In shallow water the color becomes deeper and the branching colony more compact and bush-like."

Distribution.—Cocos-Keeling; Singapore (Dana's type).

Glabro-foveolate Montiporæ.

Montipora ramosa Bernard.

Plate 62 figures 1, 1*a*, 2, 3, specimen from Murray Island. Also plate 19, figure 45, of Dr. Mayer's article.

1897. *Montipora ramosa* Bernard, Cat. Montipora, p. 49, plate 5, figs. 1–3; plate 32, fig. 3.
1907. *Montipora palmata* Bedot, Madréporaires d'Amboine, p. 272, plate 46, figs. 255–259 (*non* Dana).

Dr. Mayer collected four colonies of this species on the Murray Island reefs at the following stations:

Line II, northwest side of island, 150 feet from shore; exposed at lowest tides; bottom firm, sandy, covered with *Posidonia*-like grass.

Line II, northwest side of island, 180 feet from shore; exposed at lowest tides; bottom firm, sandy, covered with grass.

Line III, north end of island, 1,150 feet from shore; exposed at lowest tides; bottom of firm coral mud and volcanic sand, destitute of corals except this species, which grows sparingly.

As these specimens present such differences among themselves that each might almost be considered to represent a separate species, each will be briefly described:

Specimen from line II, 150 feet from shore (plate 62, figs. 1, 1*a*).—Corallum branching, base dead, base of living growth incrusting the dead part. Living part up to 62 mm. tall. Branches simple and tapering, basal diameter 7.5 mm., terminal diameter 3.5 mm., length 18 mm.; or of uniform diameter with obtuse ends; or flabellate, greatest width of an individual terminal 14.5 mm. Dividing terminals may be 40 mm. wide. Single branches dividing at the tip up to 30 mm. long. Anastomosis frequent.

Calices from 0.3 to a little more than 0.5 mm. in diameter; from 0.5 to 1 mm. apart. Cœnenchymal surface between calices flat or somewhat elevated, in the latter condition causing the calicular edges to be depressed. Both the glabrous and foveolate conditions occur on the same branch, the former usually low down on the inner sides of the branches. The reticulum is a rather open mesh-work on the upper part of the branches, but is secondarily compacted on the older parts of the corallum. In places costæ are simulated. Simple, small spines occur on projections from the cœnenchymal trabeculæ, but they do not form tubercles.

The calicular walls are distinct, rather thick rings. There are 6 distinct, spiniform septa in each calice and one longer or two opposed longer septa mark a plane of symmetry. A few smaller septa of a second cycle usually present, but the cycle is rarely or never complete.

Specimen from line II, 180 feet from shore (plate 62, fig. 3; also plate 19, fig. 45, of Dr. Mayer's article).—This is a small clump, 9 by 7 cm. in diameter and 6 cm. tall. The branches are greatly interfused. Most of the surface is glabrous, comparatively small areas having the foveolate character. Six septa are not always so conspicuously developed as in the preceding specimen.

Specimen A from line III, 1,150 feet from shore.—Corallum forms tufts; branches not much fused among themselves; round or flattened; surface usually foveolate. In some calices the second cycle of septa is complete. Minute costal striations are usual on older parts of the corallum.

Specimen B from line III, 1,150 feet from shore (plate 62, fig. 2).—Corallum forms a rounded cluster, about 8 cm. in diameter and 6 cm. tall. Branches rather slender, about 5 mm. in diameter; terminals often compressed, 7 mm. wide. Surface usually glabrous. Six principal septa not always conspicuous. Calices 0.3 to 0.5 mm. in diameter. This represents *Montipora fruticosa* Bernard.

It does not seem possible to separate these specimens into different species, but they seem to me to represent probably four or more of those recognized by Bernard, viz, *M. divaricata*, *M. compressa*, *M. fruticosa*, *M. ramosa*, and perhaps others. The name *M. compressa* (Esper) (non *Millepora compressa* L.) is not available for this species. *M. palmata* Dana from the Fiji Islands is a different species. The lower edge of the calice is protuberant and there are small cœnenchymal tubercles. Bedot's specimens identified as *M. palmata* do not belong in the same section of the genus, but are Bernard's *M. fruticosa*, which I am here combining with *M. ramosa* Bernard.

Dr. Wood Jones collected the species at Cocos-Keeling, where it grows in great luxuriance in shallow water in the lagoon, opposite the eastern end of the Pulu Tikus.

Distribution.—Cocos-Keeling (Wood Jones); Murray Island; Amboina (Bedot); Mactan, Philippines (Bernard), as *M. compressa*.

Foveolate Montiporæ.

Montipora turgescens Bernard.

Plate 62, figures 4, 4*a*, specimen from Murray Island.

1897. *Montipora turgescens* Bernard, Cat. Montipora, p. 53, plate 6, fig. 2; plate 32, fig. 11.

The following is a description of a specimen of *M. turgescens* from Murray Island:

Corallum incrusting, creeping over its basal support; edges thin, about 3 mm. thick; older part up to 10 mm. thick. Epitheca extends to the edge.

Surface foveolate. Calices crowded, apertures distinct; 0.5 to 0.7 mm. in diameter; distance apart 0.5 to 1 mm. A distinct circumscribing wall present, upper edge considerably below the cœnenchymal surface.

Septa, one complete cycle of 6 extends half-way or more than half-way to the columella. Plane of symmetry well marked by an elongate septum or by two opposed elongate septa, the inner ends of which are thickened deep down in the calice and form a columella of solid appearance. Second cycle of septa smaller, usually 4 in number; in places the cycle is complete.

Cœnenchyma, surface minutely spinulose, without papillæ or tubercles, composed of a reticulum which shows costal striations around the calices.

Station, Murray Island.—Southeast reef, line I, Lithothamnion ridge, 1,720–1,775 feet from shore.

Distribution.—Great Barrier Reef and Northeast Australia.

This is a small-calicled foveolate species, which, it seems, can only be *M. turgescens.* I strongly suspect that Bernard's *M. libera* belongs to the same species.

Montipora cocosensis, new species.

Plate 63, figures 1, 1*a*, 1*b*, specimen from Cocos-Keeling Islands.

The following is the description of this species:

Corallum forming compressed, irregularly bent, and lobate branches up to 70 mm. or more in height. Diameter of proximal end of a branch 17 by 18.5 mm.; on the same stock, a branch on the distal side of a fork, 15 by 27 mm.; 4 mm. below the end of a lobe, another stock, 6.5 by 10 mm. Ends of lobes with sloping or curved sides, or with longitudinal swellings. Calices on the branch and lobe summits as well as on the sides.

Calicular margins depressed, walls not always completely developed, where present thickish and compact. Diameter of calices, 1.25 to 1.5 mm., measured from outside of walls. Diameter of depressions in which the calices occur, 1.5 to 2.5 mm.

There are two complete cycles of septa, which frequently have a distinctly poritid arrangement. The primaries are the more prominent, and fuse by their inner ends to form a more or less compact columella. Usually there may be recognized a solitary directive, with a triplet opposite, the laterals of the triplet fusing to the columellar mass by their inner ends and not notably inclined toward the included directive. The secondaries of the lateral pairs bend toward the respective primaries and fuse to their sides near the columella. This is the scheme of the septal arrangement, but it is not uniformly regular. The septa are composed of trabeculæ which project horizontally inward, and therefore have the septal structure of *Montipora*, not that of *Porites*, in which the septa are composed of ascending trabeculæ with cross fusions. The larger septa are laminate; no suggestion of pali.

The cœnenchyma is composed of a wide, axial streaming layer, the threads bending outward and surging upward into a crest, usually sharp, between the calices. Summits with minute radial striations and some small points, but no tubercles. The surface of the reticulum is flaky in appearance.

One process has grown downward and formed a concavity, arched upward, in which the characters of the lower surface are shown. The calices are from less 0.5 mm. to about 0.75 mm. in diameter; from 0.5 to more than 1.5 mm. apart; circumscribing walls as distinct rings, usually slightly protuberant. Septa distinct, small; cyclical development irregular. Cœnenchyma, surface plane; forms an open, rather loose reticulum.

Habitat, etc., Cocos-Keeling Islands.—Dr. F. Wood Jones states as to these specimens:

"Common in the inlets and on the lagoon side of barrier flats, at the southern side of the lagoon. Color, while alive, a rather conspicuous yellow; zooids, paler."

This species belongs in Bernard's section Foveolate Montiporæ, and in the subdivision of this section in which the branching forms are placed. He includes the following species, viz, *M. gaimardi* Bernard, *M. indentata* Bernard, *M. palmata* (*non* Dana), *M. rigida* Verrill, *M. limitata* (Ellis and Solander). It is no one of these.

The similarity in its septal arrangement to *Porites* is interesting, and suggests, as had previously been maintained by Duerden,[1] the close kinship of the Poritidæ and Acroporidæ. However, as the foregoing description shows, the genus is clearly *Montipora.*

Papillate Montiporæ.

Montipora venosa (Ehrenberg).

Plate 63, figure 3, specimen from Murray Island. Also plate 19, figure 46, of Dr. Mayer's article.

1897. *Montipora venosa* Bernard, Cat. Montipora, p. 69, plate 32, fig. 15 (synonymy).
1907. *Montipora venosa* Bedot, Madréporaires d'Amboine, p. 274, plate, 46, figs. 260–262; plate, 47, figs. 263–266.

The following is a description of specimens of *Montipora venosa* from Murray Island:

Corallum forms thickish, undulating or rugose plates which are as much as 3 cm. or somewhat more thick 10 cm. from the edge; obtuse or rounded on the edge, 3 to 13 mm. thick. Upper surface caliculate all over; lower caliculate up to 4 cm. from the edge. No well-developed epitheca, in places a few epithecal threads.

Calices on upper surface from 1 to 1.25 mm. in diameter, therefore rather large and open; distance apart from 0.5 mm. to 2 mm., crowded where there are no papillæ, distant where papillæ are present. Margins depressed, walls distinct or scarcely distinguishable from the cœnenchymal reticulum. In places no distinction can be made between the two surfaces; in others, the calices of the under surface are smaller, 0.75 mm. in diameter, and are separated from 1 to 2 mm. by flat cœnenchymal surfaces.

Septa in two complete cycles, primaries long, frequently all 6 fuse in the axis and form a false columella; plane of symmetry distinct. Secondaries smaller, usually but not always well developed; occasionally one fuses to the side of a primary near the axis.

Cœnenchyma loose-textured; edges translucent; the downward-bending threads may be almost suppressed, or the threads may be symmetrically arranged with reference to a plane of divergence. Over considerable areas the surface may be foveolate; over other areas papillæ are irregularly developed, they may fill an interspace between calices, or may be elongate from one to 4 calicular spaces, length of ridges of latter kind up to 9 mm., height up to 2 mm. Little spines project from the angles and points of fusion of many of cœnenchymal threads.

Stations, Murray Island.—Southeast reef, line I:

1,400 feet from shore; water 14 inches deep; bottom hard, rocky.
1,640 feet from shore; water 15 inches deep at lowest tide; hard, rocky bottom.
Lithothamnion ridge, 1,720 to 1,775 feet from shore.

The foregoing description is based on 2 specimens 1,400 feet from shore.

In the specimen 1,640 feet from shore, the texture is more compact; over the humpy part of the corallum the calices are crowded, separated by thin walls, but papillæ, slender and erect or rather thick with densely spinulose surfaces, are developed between the calices.

The specimen from the Lithothamnion ridge is simply foveolate, without papillæ. The texture of its cœnenchyma is more regular and somewhat closer, and the second cycle of septa is more uniformly well developed.

The specimens from these three stations might be referred to as many species, but the general growth-habit is the same, as also are the calicular and septal characters and the arrangement of the cœnenchymal threads. The variations consist in relative compactness and regularity of the structure of the cœnenchyma, the crowding of the calices, and the development of the papillæ.

The species belongs in the subgroup of Papillate Montiporæ designated by Bernard "Papillæ irregular" and satisfies the requirements of *Montipora venosa* (Ehrenberg). In its calicular characters, by possessing 6 well-developed primary

[1]Mem. Nat. Acad. Sci., vol. 8, pp. 542 *et seq.*, 1903.

septa, usually 6 well-developed secondaries, and a pseudocolumella, it resembles *M. verrucosa*, but the papillæ of the latter species have not the tendency to irregular fusion and more definitely occupy intercalicular areas.

Distribution.—Red Sea; Amboina; Fiji Islands.

Montipora spumosa (Lamarck).

Plate 63, figures 2, 2*a*, specimen from Cocos-Keeling Islands.

1897. *Montipora spumosa* Bernard, Cat. Montipora, p. 71, plate 8, fig. 1; plate 11; plate 32, fig. 16.
1907. *Montipora spumosa* Bedot, Madréporaires d'Amboine, p. 277, plate 48, figs. 267–270.

It does not seem necessary to repeat descriptions of this species.

Habitat and color, Cocos-Keeling Islands.—Dr. F. Wood Jones states:

"Rough water, barrier north of Pulu Bras and the barrier on southern side of the atoll. Abundant, usually yellow or brown in color."

Distribution.—Cocos-Keeling (previously reported by Bernard); Lacépède Island, Northwest Australia; Rocky Island, Great Barrier Reef; Tongatabu.

Montipora elschneri new species.

Plate 64, figures 1, 1*a*, specimen from Fanning Island.

The description of this species follows:

Corallum an irregularly shaped, thick plate. The horizontal dimensions of the type are about 90 by 93 mm.; thickness ranges from 16 to 35 mm. Usually there is no free edge. The older part of the corallum had mostly been killed, and regenerated living tissue had incrusted it. The surface is irregularly undulate, with small depressions and low elevations.

Calices from 0.5 to 1.0 mm. in diameter, between 0.6 and 0.7 mm. the usual diameter. The primary septa well-developed, the directives meeting and forming a more or less plug-like columella, which is deep-seated. The other primary septa appreciably smaller, but they sometimes extend to the columella. The secondary septa are much smaller than the primary, but they are usually distinct in at least three systems, and often the cycle is complete. Corallite walls distinct.

The calices present three conditions in their relations to the cœnenchymal surface. The intervening cœnenchymal surface may be flat, when the distance between the calices is from 0.5 mm. in depressions to 1.5 mm. on areas which are not depressed. In some areas, which are relatively small, the cœnenchyma rises beyond the calicular rims and produces foveolate calices. In other areas the cœnenchyma forms papillæ between the calices. These are low and their sides slope upward to the apex; often they neatly fill an intercalicular space and have a basal diameter of about 2 mm. Sometimes 3 or 4 papillæ fuse and form series up to between 5 and 6 mm. long. Occasionally a calicular opening has been carried upward by the upward growth of cœnenchyma on all its sides, but the cœnenchymal surface is not of the same height all around the calice. This species is one of the group which Bernard characterizes as "Papillæ irregular."

The cœnenchymal surface is reticulate, delicately spinulose in places, with fine costal markings.

Locality.—Fanning Island (Carl Elschner, collector).

Type: U. S. National Museum.

Bernard places the following 10 species in the group to which *M. elschneri* belongs, viz, *M. venosa* (Ehr.), *M. spumosa* (Lam.), *M. ænigmatica* Bernard, *M. brueggemanni* Bernard, *M. lanuginosa* Bernard, *M. flammans* Bernard, *M. lobulata* Bernard, *M. edwardsi* Bernard, *M. acanthella* Bernard, and *M. fungiformis* Bernard. *M. venosa* and *M. spumosa* have already been considered. Of the others the following have calices between 0.5 and 1.0 mm. in diameter: *M. lanuginosa*, *M. lobulata*, *M. edwardsi*, and *M. acanthella*. *M. lanuginosa* has an "explanate, thin, translucent" corallum; *M. lobulata* forms an irregularly lobate mass; *M. edwardsi* forms "tufts of columns rising vertically from an irregular platform"; and *M. acanthella*

is incrusting with "free drooping outgrowths." Regarding the last-mentioned species Bernard says:

"The coral is peculiar in the irregular distribution and shapes of the papillæ, and in the jagged processes which grow out of them by the secondary budding of young calices from their surfaces, accompanied by secondary formation of sharp ridges or papillate points."

It therefore appears that Bernard did not consider *M. elschneri* in his work; and it certainly is not in von Marenzeller's report on the *Pola* Red Sea corals.

It gives me pleasure to attach to this coral the name of Mr. Elschner, who collected the type and has made important contributions to our knowledge of the geology of several coral-reef areas in the Pacific.

Montipora sp.

Plate 64, figures 2, 2*a*, specimen from Cocos-Keeling Islands.

The following is a description of *Montipora* sp. from Cocos-Keeling Islands:

Corallum represented by the terminal of a branch or lobe. Length 25 mm.; basal diameter, 12 by 18.5 mm.; apex, bilobate, obtuse, 27.5 mm. wide; maximum thickness just below summit, 9.5 mm. Calices absent or very irregularly developed on the summit.

Calices somewhat irregularly distributed, in places tend to form radial series of 3, 4, or 5 calices; in other places to form series of a few calices, 2 or 3, roughly parallel to the growing edge. Calicular walls rarely distinct from the surrounding cœnenchyma. Diameter of fully developed calices, 1.25 to 1.5 mm. Diameter of depressions 2 to 2.5 mm.

Septa, 6 distinct primaries, most of which may fuse in the axis to form a rather small but distinct columella; a few small secondaries, but the cycle is rarely or never complete.

Cœnenchyma with an axial streaming layer, which forms a frothy reticulum on the branch summits; on sides of the branch the cœnenchyma rises up between the calices, producing either subacute or rounded, crowded ridges, or tends to form low, rounded protuberances, especially on the lower sides of the calices. It is delicately spongy, with a minutely spinulose surface; minute striations run down the sides of the depressions to the level of the calicular opening.

Habitat, Cocos-Keeling Islands.—Dr. Wood Jones states that this species occurs with *Montipora cocosensis*, in the inlets and on the lagoon side of barrier flats, at the southern side of the lagoon.

This species has a growth-form similar to that of *M. cocosensis*, but the distribution of the calices, septal characters, and cœnenchyma are strikingly different. It belongs to the Papillate Montiporæ (papillæ in close relation to the calices as hoods, underlips, etc.), whereas the former is one of the Foveolate Montiporæ.

Bernard refers the following 8 species to the subgroup of *Montipora* to which this species belongs, viz: *M. bilaminata* Bernard, *M. guppyi* Bernard, *M. tubifera* Bernard, **M. cristagalli* (Ehrenberg), **M. gracilis* Klunzinger, **M. spongiosa* (Ehrenberg), **M. circumvallata* (Ehrenberg) and **M. stalagmites* Ortmann. The last 5, marked by an asterisk (*), are lobate, tufted, or branching, all of which except *M. stalagmites* Ortmann come from the Red Sea. Of these 5 only 2 have large calices, *M. cristagalli* (0.5 to 1 mm.) and *M. spongiosa* (1 mm.); but the calices of both of these are smaller than in the present species and both differ from it in the character of their cœnenchyma (see figures by Klunzinger). Notwithstanding the presence of underlips to many calices, Bernard's account of the branching and lobate species of the Foveolate Montiporæ was searched to ascertain if he had described it as a member of that subgroup. The only one to which there appears any possible relation is *M. multiformis* Bernard, but neither the description nor the figures indicate the presence of underlips to the calices. There is considerable resemblance to *M. foveolata* (Dana) and *M. socialis* Bernard, but in both of these,

according to Bernard, the secondary septa are well developed and are subequal to the primaries. Because of the small size of the fragment, although I am unable to refer it to any described species known to me, I am not giving the specimen a specific name.

Montipora verrucosa (Lamarck).

1816. *Porites verrucosa* Lamarck, Hist. nat. Anim. sans Vert., vol. 2, p. 271.
1897. *Montipora verrucosa* Bernard, Cat. Montipora, p. 103, plate 19, fig. 2.
1907. *Montipora verrucosa* Vaughan, U. S. Nat. Mus. Bull. 59, p. 160, plate 53–59 (all figs.).

Mr. Elschner collected at Fanning Island a specimen which is duplicated by the part of the specimen shown in the background of plate 57, figure 1, of my paper cited in the synonymy, *i. e.*, the growth-form is subramose, and either single papillæ or two or three papillæ fused into series occur on the branch summits. It seems to me that this series of specimens, including those from the Hawaiian Islands, may connect with *Montipora circumvallata* Ehrenberg, as described and figured by von Marenzeller,[1] but without actual comparison of specimens only a suggestion is warranted.

Distribution.—Great Barrier Reef; Fanning Island (Elschner); Hawaiian Islands

Tuberculate Montiporæ.

Montipora informis Bernard.

Plate 64, figures 3, 4, 4*a*, 4*b*, 4*c*.

1897. *Montipora informis* Bernard, Cat. Montipora, p. 133, plate 27, fig. 2; plate 34, fig. 3.

The following is Bernard's description of this species:

"Corallum encrusting, with free, generally drooping edges, 3 to 4 mm. thick, and without supporting epitheca. The upper surface rises into shapeless angular masses, pointed and jagged; these incorporate by encrustation foreign organisms. Other upgrowths are nearly flat, bifrontal laminæ or folds, sloping outwards from the faces of the drooping margins.

"Calices conspicuous, scattered, 1.5 to 2 mm. apart, 0.75 mm. in diameter; deep open fossa. Two cycles of short, rather regular septa, the secondaries smaller than the primaries. The latter spring directly out of the jagged tubercles which surround the calices, except when the latter are immersed in delicate reticulum; in this case the aperture is clear and round, the septa only appearing some distance below the surface. On the under surface the calices are smaller, rather more numerous, and generally surrounded with a protuberant cœnenchymatous ring.

"The cœnenchyma is a fragile, delicate reticulum, which forms in irregular patches (generally giving rise to slight eminences or ridges) stout distinct trabeculæ joined by very thin junctions. These trabeculæ at such points rise above the surface to form short ragged tubercles, the long delicate points of which may meet and fuse like thin hyphal threads spread over the surface. In the valleys and on the flatter surfaces the reticulum comes to the surface as a delicate open lacework immersing the calices. In some of the deep valleys the calices may be protuberant as thin, white, membranous but perforated cylinders visible to the naked eye. The reticulum forms the substance of the coral except where stout trabeculæ have been developed. It is possible with a pocket lens to see down between the trabeculæ, so open and fragile is the cœnenchyma.

"There are two specimens of this coral which can, however, be fitted together, the smaller being but a detached, jagged excrescence from the surface of the larger (see plate XXVII). The two together show the luxuriance of the growth. It is worth noting that the tubercles are especially developed on prominences and small branch-like lobes. This same feature is seen also in *M. hispida* and *M. trabeculata*. As in this latter case, this peculiarity accounts for the absence of the axial reticulum from the sections of broken knobs.

"The type specimen has encrusted the dead remains of a former growth. This latter appears also to have grown in the same irregular amorphous fashion. There is no trace of

[1] Denksch. k. k. Akad. wiss. Wien., vol. 80, p. 62, plate 21, figure 70; plate 23, figure 70*a*, 1906.

any of the preceding dead growth in the axis of the large detached excrescence (*b*); this fact shows how richly the corallum sends up its irregular masses.

"*a*. Murray Island, Torres Straits. 85. 6. 30. 3. (Type).

"*b*. (Fragment of same specimen)."

Dr. F. Wood Jones has sent to the U. S. National Museum two pieces, evidently representing one species of *Montipora*, which grows on the barrier of Cocos-Keeling. A description of these pieces follows:

One piece represents the expanding lamina of the base (plate 64, figs. 4, 4*a*, 4*c*). It is 82 mm. long, from 41 to 53 mm. wide; up to 9 mm. thick back from the edge; edge about 3 mm. thick. Upper surface undulate, with one low hillock; lower surface more even, epitheca ranges from 8 to 38 mm. from the edge. Living tissue somewhat reflected under the edge.

Calices on upper surface about 0.75 mm. in diameter, margins sunken, boundaries usually distinct and rather thick; on lower surface distinct, about 0.5 mm. in diameter, margins flush with the surface or slightly protuberant, surrounded by distinct, thickish, ring-like walls.

Septa on the upper surface, two well-developed cycles; of the primaries, 4 are about as long as half a radius, 1 or 2 directives longer; the 6 primaries may meet in the bottom of the calice to form a weak columella. Lower surface, two cycles present, but smaller than on the upper surface.

Cœnenchyma, streaming layer nearer the lower than the upper surface. On lower surface much compacted within the epitheca. Outside the epitheca it forms a flat, open reticulum between the calices. On the upper surface trabeculæ grow upward and form erect, densely frosted tubercles which are intimately connected with the septa on the outer edges of the calicular walls. Frequently they form palisades surrounding the calicular apertures, and sometimes are fused one to another. In places where the calices are sufficiently distant from one another there are tubercles in the interspaces. The reticulum is loose, so that openings may be seen between the tubercles.

The other specimen (plate 64, fig. 3) represents a lobate protuberant above the explanate base. It is 67 mm. tall, and is most irregular in its subdivisions, which may be pointed or obtuse with ends about 7 mm. in diameter and without tubercles on the terminals. The calicular characters and the tubercles are similar to those of the upper surface of the basal part of the colony. The surface is spiny, the tubercles are up to 1.5 mm. tall, and may be loosely fused in rings around the calices or in places there are indefinite indications of loose radial fusion.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones remarks that this species "lives on the barrier; exposed parts of zooids is fine purple."

This species greatly resembles *Montipora hispida* Dana, from which it differs by having the tubercles closely associated with the calicular margins, whereas in the latter they stand back from the calicular margins. It is also close to *M. stellata* Bernard; in fact, the latter is probably based on the explanate basal part of a corallum.

Bernard describes 15 species of *Montipora* which have separate tubercles that tend to form rings or palisades around the calices, and three others may have the tubercles associated with the calicular margins. Of these, 6 are reported from the Great Barrier Reef or Torres Strait: *M. variabilis* Bernard, *M. stellata* Bernard, *M. lichen* Dana, *M. granulata* Bernard, *M. æquituberculata* Bernard, and *M. informis* Bernard. On page 158 is a tabular summary of the characters of these species, except *M. lichen*, which is not closely related.

The coral on which the next description is based belongs in this group and is very close to *M. informis* and *M. stellata*, but it does not precisely accord with either. As a sufficiently large suite of specimens for ascertaining its range of variation is not available, it can not be determined whether it is a distinct species or only a variant. Under these circumstances it seems best merely to indicate its relationship with the nearest recognized species.

Characters of some Tuberculate Montiporæ from Australia.

Name.	Growth-form.	Calices.	Septa.
M. variabilis. . . .	Incrusting, following surface of substratum.	0.5 mm. in diameter. .	Variable, absent, or 2 cycles of short, thick septa.
M. stellata.	Not closely incrusting, free edges.	Elegantly star-shaped, 0.5 to 6.75 mm. in diameter.	6 well-developed primaries; secondaries smaller, irregular.
M. granulata	Large explanate fronds; thin edges.	0.5 mm. in diameter.	6 primaries, no secondaries.
M. æqui-tuberculata. .	Thin, explanate. .	0.5 mm. in diameter. .	6 not very symmetrical primaries; a few rudimentary secondaries.
M. informis.	Incrusting base, free edges, upper surface rising into irregular, pointed, jagged masses.	0.75 mm. in diameter.	2 cycles; short, rather regular primaries; secondaries shorter than the primaries.

Montipora aff. M. informis Bernard.

Plate 65, figures 1, 1*a*, specimen from Murray Island. Also plate 19, figure 47, of Dr. Mayer's article.

The following is a description of *Montipora* aff. *M. informis* from Murray Island:

Corallum, represented by a triangular fragment, forms a thin, expanding free lamina. Length of radius of fragment 12.2 cm.; thickness near inner end, 1 cm.; thickness of edge, 2 mm. Both upper and lower surfaces undulating. Epitheca on lower surface ranges from 4 mm. to 19 mm. from edge.

Calices on upper surface from 0.5 to 1 mm. in diameter, distance apart from about 0.5 mm. to 1.5 mm., arranged in rows roughly concentric with growing edge. Walls usually not well marked. On lower surface diameter averages about 0.5 mm.; distance apart 0.5 to 1.5 mm., walls distinct, usually slightly elevated. Septa on upper surface, in two distinct, complete cycles, first cycle only slightly the more prominent, plane of symmetry distinct. Usually an axial thickening of the ends of the directive septa simulates a columella. On lower surface, cycles irregular, septa faintly developed.

Cœnenchyma of upper surface glabrous or tuberculate. Tubercles where present either surround the calices or are especially developed on the proximal sides. They are small, 4 or 5 to half a calicular circumference, erect, and densely frosted. Reticulum rather coarse, becomes secondarily compacted.

Station, Murray Island.—Southeast reef, line I, 1,400 to 1,450 feet from shore, water 14 inches deep at lowest tide; hard, rock bottom of broken corals; about 200 feet inward from the inner edge of the breakers.

This coral differs from *M. informis* by the thickening of the inner ends of several primary septa on the upper surface to form a columella plug, by the irregular septal development in the calices on the lower surface, and by a less uniform development of the tubercles on the upper surface.

Montipora verrilli Vaughan.

1907. *Montipora verrilli* Vaughan, U. S. Nat. Mus. Bull. 59, p. 168, pl. 63, figs. 2, 2*a*, 2*b*; pl. 64, figs. 1, 1*a*.

Mr. Elschner obtained at Fanning Island a specimen which is essentially typical, except that the surface is not so corrugate as that of the cotypes. Its dimensions are 140 mm. long, 135 mm. wide, and about 70 mm. thick. The calices and septa are as in the cotypes.

Distribution: Hawaiian Islands; Fanning Islands.

Montipora foliosa (Pallas) Bernard.

Plate 65, figures 2, 2*a*, 2*b*.

1897. *Montipora foliosa* Bernard, Cat. Montipora, p. 158, plate 30, plate 34, fig. 14 (synonymy).
1907. *Montipora foliosa* Bedot, Madréporaires d'Amboine, p. 280, plate 50, figs. 275-279.
1910. *Montipora* Wood Jones, Coral and Atolls, plate 2 (opposite p. 74).

Description not needed.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones says of this species:

"Lives exclusively in the lagoon and most abundantly to the west of Pulu Selma. The large cabbage-like colonies grow upon the sides of composite mounds that rise up in this part of the lagoon and are present on a somewhat restricted area in great luxuriance. While alive the colony is colored olive brown or olive green, the zooids somewhat paler."

Distribution.—Mauritius; Ramesvaraam; Cocos-Keeling; Amboina; Zamboanga, Philippines; Api, New Hebrides.

Genus ACROPORA Oken.

1815. *Acropora* Oken, Lehrb. Naturg., Th. 3, Abth. 1, p. 66.
1902. *Acropora* Verrill, Trans. Conn. Acad. Arts and Sci., vol. 11, pp. 164, 208 (with synonymy).

Type species: *Millepora muricata* Linnæus, s.s. = *Madrepora cervicornis* Lamarck.

The names of the species reported by Brook from Australia and their geographic distribution according to him are given in the following table:

Species of Acropora reported by Brook from Australia.

Name.	Localities.
Subgenus *Eumadrepora* Brook.	
Acropora muricata (Linn.) forma palmata (Lam.)	Florida; St. Thomas; Pedro and Morant Cays, Caribbean Sea; Jamaica; Port Darwin; Singapore.
forma prolifera (Lam.)	Barbados; Caribbean Sea; Wreck Bay, Great Barrier Reef; Northeast Australia; St. Vincent, West Indies; St. Thomas.
forma cervicornis (Lam.)	St. Thomas; Barbados; Florida; St. Christopher; Port Darwin; Thursday Island.
[1]secunda (Dana)	Port Denison; Baudin Island, Northwest Australia; Tizard Bank; Singapore.
†arbuscula (Dana)	Singapore; Sulu Sea; Great Barrier Reef.
grandis (Brook)	Palm Island; Herring Island, Bowen; Rocky Island.
†formosa (Dana)	Nias Island, Sumatra; Thursday Island.
*pulchra (Brook)	Keeling Island; China Sea; Torres Strait; Great Barrier Reef.
valenciennesi (M. Edw. & H.)	Ceylon; Thursday Island; Torres Straits.
laxa (Lamarck)	Seychelles; Rodriquez; Palm Island; Rocky Island; Warrior Island; Low Woody Island; Macclesfield Bank.
*decipiens (Brook)	Rocky Island Reefs; Low Woody Island Reefs; Thursday Island; Green Island; Santa Anna Island; Solomon Islands; Mola Island, New Hebrides; Capricorn Islands.
*abrotanoides (Lam.)	Tahiti; Singapore; Rocky Island.
affinis (Brook)	Darnley Island; Cleremont Island; Macclesfield Bank.
pocillifera (Lam.)	Api, New Hebrides; Tongatabu; Port Denison; Lady Elliott Island; Baudin Island, Northwest Australia; Rocky Island; Green Island; Low Woody Island; Fiji Reefs.
†aspera (Dana)	Mactan Island; Zamboanga; Warrior Island; Rocky Island.
†divaricata (Dana)	Port Denison; Eagle Island; Amirante Islands; African Island; Seychelles.
*squarrosa (Ehrenb.)	North Australia; Bellona Shoal, east of Australia.
Subgenus *Odontocyathus* Brook.	
Acropora ambigua (Brook)	Northumberland Island.
Subgenus *Polystachis* Brook.	
Acropora nasuta (Dana)	Tahiti; ?Fiji; Capricorn Islands.
*digitifera (Dana)	Rocky Island; Capricorn Islands; Madagascar.
effusa (Dana)	Ceylon; Palm Island; Rocky Island.

[1]The specimens from Port Denison and Baudin Island, referred by Brook to *A. secunda* (Dana), have been named *A. secundella* by Verrill. Trans. Conn. Acad. Sci., vol. II, p. 235 (in footnote), 1902.

Species of Acropora reported by Brook from Australia—continued.

Name.	Localities.
Subgenus *Polystachis* Brook—con.	
Acropora capillaris (Klunzinger)....	?Port Denison; ?Rocky Island.
†tenuis (Dana)	Zamboanga; Wreck Bay, Great Barrier Reef; Tizard Bank.
†cerealis (Dana)..........	Wreck Bay; Port Denison; Low Woody Island; Rocky Island; Mauritius; Ternate; Amboina; Seychelles; Tongatabu; Singapore.
*†spicifera (Dana).	South Seas; James Town, St. Helena; Tongatabu; China, probably south; ?Treasury Island; Solomon Islands; ?Moreton Bay; Tizard Bank.
*pectinata (Brook) . .	Thursday Island; Capricorn Islands; Wreck Bay, Great Barrier Reef.
*corymbosa (Lam.).	Aden; Rodriquez; Tizard Bank; Wreck Bay, Great Barrier Reef; Blackwood Bay; Red Sea; Fiji; Ramesvaram; Rocky Island.
†surculosa (Dana)... ..	Tahiti; Low Woody Island; Capricorn Islands; Rocky Island; Ramesvaram.
anthocercis (Brook)..	Palm Island; Rocky Island.
recumbens (Brook)...	Rocky Island; Green Island; Capricorn Islands.
†hyacinthus (Dana)	Fiji Islands; Tizard Bank; Palm Island.
conferta (Quelch).........	Reefs, Fiji; Kandavu, Fiji; Levuka, Fiji; Tongatabu; Eagle Island, Amirante Islands; Rocky Island; Cleremont Island; Thursday Island; Rodriquez.
delicatula (Brook).	Treasury Island, Solomon Islands; Port Denison.
kenti (Brook)..	Thursday Island; Low Woody Island.
patula (Brook)	Port Denison.
latistella (Brook)..	Port Denison; Thursday Island.
Subgenus *Lepidocyathus* Brook.	
Acropora millepora (Ehrenb.) . ..	Cleremont Island; Port Denison; Low Woody Island; Rocky Island; Thursday Island; Green Island; Capricorn Islands; Ceylon.
†convexa (Dana)..	Tongatabu; Singapore; Port Denison.
†prostrata (Dana).........	Fiji Islands; Capricorn Islands; Thursday Island; Low Woody Island.
*squamosa (Brook)..	Cleremont Island; Rocky Island.
selago (Studer)	Flat-top Island, near Marburg; Low Woody Island; Thursday Island.
†cribripora (Dana)........	Fiji Islands; Tongatabu; Palm Island.
*sarmentosa (Brook)......	Port Denison; Rocky Island; Capricorn Islands.
*†thebes (Dana)...........	Kandavu, Fiji; Fiji Reefs; Capricorn Islands; Rocky Island; Low Woody Island; Warrior Island; Green Island; Thursday Island; Straits of Malacca.
obscura (Brook)...........	Ramesvaram; Rocky Island; Low Woody Island.
monticulosa (Brueg.).......	Rodriquez; Capricorn Islands.
Subgenus *Isopora* Studer.	
*palifera (Lam.).....	Sulu Sea; China Sea; northeast Queensland; Capricorn Islands; Port Denison; Palm Island; Thursday Island; New Guinea; Solomon Islands; Tizard Bank; Diego Garcia.
†cuneata (Dana)....	Fiji; Capricorn Islands; Rocky Island.
*plicata (Brook)...........	Tongatabu; Rocky Island.
Subgenus *Tylopora* Brook.	
Acropora eurystoma (Klunzinger)...	Kosier, Red Sea; Maldive Islands; Diego Garcia; Thursday Island.
fruticosa (Brook)	Port Denison; Warrior Island.
amblyclados (Brook)......	Indian Ocean; Singapore; Australia.
diversa (Brook)...........	Diego Garcia; Thursday Island.
spectabilis (Brook)	(?)
*gemmifera (Brook)	Rocky Island; Capricorn Islands; Kandavu, Fiji; Thursday Island; Evans Bank, Arafura Sea.
†humilis (Dana) ...	Fiji Islands; Palm Island; Adolphus Island.
brueggemanni (Brook)...	Singapore; Northeast Australia; Warrior Island; Palm Island; Port Denison; Thursday Island; Rocky Island; Wreck Bay, Great Barrier Reef; Tizard Bank.
ortmanni (Brook)....... .	Ponapé; Bowen, Queensland.

Species of Acropora reported by Brook from Australia—continued.

Name.	Localities.
Subgenus *Tylopora* Brook—con.	
Acropora klunzingeri (Quelch)(syn. of *A. hemprichii* (Ehr.))	Red Sea.
cophodactyla (Brook)	Habitat not recorded.
seriata (Ehrenb.)	Red Sea; Indian Ocean; Tongatabu; Low Woody Island; Capricorn Islands; Troughton Island.
*canaliculata (Klunzinger). (Syn. of *A. scherzeriana* Brueg.)	Port Denison.
bullata (Brook)	Port Denison.
australis (Brook)	Darnley Island; Wreck Bay, Great Barrier Reef; Low Woody Island.
erythræa (Klunzinger)	Red Sea; Wreck Bay, Great Barrier Reef; Maldive Islands.
bæodactyla (Brook)	Capricorn Islands; Rodriguez.
brevicollis (Brook)	Torres Strait; Great Barrier Reef; Rodriguez.
Subgenus *Conocyathus* Brook.	
Acropora *variabilis (Klunzinger)	Kosier, Red Sea; Indian Ocean; Tongatabu; Capricorn Islands; Port Denison; Ceylon; Macclesfield Bank.
glauca (Brook)	West Australia.
loripes (Brook)	Green Island; Rocky Island; Capricorn Islands.
violacea (Brook)	Fiji; Green Island, Great Barrier Reef.
†valida (Dana)	Fiji Islands; Tongatabu; Thursday Island; Singapore; Mergui Archipelago.
microphthalma (Verrill)	Ramesvaram; Thursday Island; China (probably South); Tsusima, Straits of Korea.
exilis (Brook)	Macclesfield Bank; Evans Bank, Arafura Sea; Seychelles.
elseyi (Brook)	North Australia; Thursday Island; Rocky Island.
Subgenus *Rhadocyathus* Brook.	
Acropora hemprichii (Ehrenb.)	Kosier, Red Sea; Ceylon; Port Denison; Shortland Island, Solomon Islands.
*syringodes (Brook)	Palm Island; Samoa; South Seas.
†carduus (Dana)	?Australia; ?Malacca.
*†rosaria (Dana)	Ponapé, Caroline Islands; Samoan Islands; Tongatabu; Fiji; Duchâteau Islands; Louisiade Archipelago; Port Denison; Palm Island; Low Woody Island; Thursday Island; Port Darwin.
Subgenus *Trachylopora* Brook.	
Acropora †echinata (Dana)	Australia; Pacific Ocean.
Subgenus *Distichocyathus* Brook	No species recorded from Australia.

The total number of species definitely reported from Australia is 74, to which I have added the names of 4 species the locality of which is not given or which are questionably referred to Australia. I have marked with an asterisk (*) the names of 18 species which are specially considered in the present paper; and have indicated with a dagger (†) those of Dana's species of which the types are in the U. S. National Museum. It is not practicable here to review the species of *Acropora* reported from the Great Barrier Reef, as such a task is probably not possible without a critical study of Brook's types and of the other specimens examined by him. However, I will say that I doubt if half as many species as he recognized will be found valid. Recent studies, especially those by von Marenzeller, of the variation in the corallum of species of *Acropora* have shown it to be enormous. It appears that Brook has often described as species the vegetational variants of the same species; but without critical study of large suites of specimens it is hazardous to attempt to revise the synonymies. It is highly improbable that Brook is correct in his reference of certain Great Barrier Reef specimens to the same species as that to which the West Indian members of the genus belong.

In the present paper one previously named species, *A. haimei*, is reported from Australia for the first time; another species, *A. murrayensis*, is described as new, but it was probably included under *A. rosaria* by Brook.

Acropora (Eumadrepora) pulchra (Brook).

Plate 66, figures 3, 3*a*, a specimen from Cocos-Keeling Islands.

1893. *Madrepora pulchra* Brook, Cat. Genus Madrepora, p. 44, plate 28, fig. A.
1907. *Madrepora* Wood Jones, Proc. Zool. Soc. London for 1907, plate 17, fig. 2, *b* (right-hand figure)
1910. *Madrepora* Wood Jones, Coral and Atolls, p. 89, fig. 24, *b* (right-hand figure).

Brook based this species on a specimen collected by H. O. Forbes in Keeling Island. Dr. Wood Jones has collected one branch which seems referable to it. The branch is 14.5 cm. long; 9 mm. in diameter at the lower end; axial corallite damaged, about 3.5 mm. in diameter. There are no subdivisions and only one proliferous corallite. Two cycles of septa well developed in the axial corallite. Cœnenchyma of loose texture. The character of the radial corallites are as described by Brook.

This specimen differs from Brook's description, and also from the Murray Island specimens of var. *alveolata*, largely in its greater attenuation, without subordinate branching; but this character, as well as the loose texture, may be due to its habitat, in quiet lagoon water.

Habitat, Cocos-Keeling Islands.—Dr. F. Wood Jones states that the species lives in still water, within the lagoon area.

Acropora (Eumadrepora) pulchra var. alveolata (Brook).

Plate 66, figures 1, 2, specimen from Murray Island.

1893. *Madrepora pulchra* var. *alveolata* Brook, Cat. Genus Madrepora, p. 45, plate 28, fig. C.

The following description is based on one larger and four smaller fragments, all perhaps from one colony, collected 1,000 feet from shore, Murray Island:

Corallum loosely branching; frequently 3 or 4 branches from the same level; angle with main stem 45° or greater. Main stems and branches slender, slowly decreasing in diameter toward the apex. One branch measures 78 mm. long; 9.3 mm. in diameter at base; axial corallite at tip of branch, 3 mm. in diameter. A broken branch on the same specimen is 68 mm. long; diameter at base 10 mm.; at end, 6.5 mm.; decrease in diameter, 3.5 mm. in 68 mm., or about 1 mm. to 20 mm. in length. Other specimens show still more gradual tapering.

Axial corallite, diameter about 3 mm.; protuberant, about 3.5 to 4 mm.; diameter of calicular aperture, about 1 mm. Walls of the corallite about 1 mm. thick; structure reticulate, porous, but the area of the solid elements exceeds that of the pores; outer surface with longitudinal, plate-like costules, between which are numerous synapticulæ, their margins subentire near the calicular aperture, but irregularly dentate near the level of the uppermost radial corallites. Septa, 12 in number, primaries the more prominent, nearly meeting deep down in the calice; secondaries smaller but distinct.

Radial corallites of two kinds, protuberant and immersed or subimmersed. The protuberant calices are more prominent near the ends of branches, where they may project as much as 2.25 mm. The outer wall is often somewhat thickened; it may be nearly perpendicular or may make an angle of about 45° with the surface of the branch, while the plane of the aperture is either nearly at right angles to the branch, or it may be slightly lower next the branch than on the sides of the corallite, with a slight excavation of the outer margin. The inner wall is distinguishable, sometimes free, but usually not protuberant. The texture of the wall is porous, the outer edge thin and often somewhat ragged; plate-like costules are distinct on the lower, outer surface. The calicular apertures are broadly elliptical, with longer axis in the radial plane, or subcircular; diameter about 1 mm. The directive septa conspicuous; other primaries small, but distinguishable; two secondaries, one on each side

of the outer directive usually visible; other secondaries obscure or absent. Distance between the walls of adjacent protuberant corallites usually about 1 mm. Toward the base of branches and on the lower part of main stem, all corallites may become immersed by the outward growth of the cœnenchymal tissue; the calicular apertures may become smaller, 0.75 mm. in diameter, and more distant. The immersed and subimmersed corallites need no special description.

The cœnenchymal surface near the tips of branches is loosely reticular, porous, somewhat flaky, and with irregular granulations projecting above the reticulum. On the old portions of the corallum the reticulum is coarser, but it is still porous, and granulations occur in wavy rows.

Stations, Murray Island.—Southeast reef, line I:

600 feet from shore; water 4.5 to 5 inches deep; bottom sandy; 4 fragments, terminals of branchlets.
1,000 feet from shore; water 14 to 17 inches deep; bottom rocky; specimens described.
1,400 feet from shore; water 14 to 15 inches deep; bottom rocky, broken coral; 2 broken branches.
1,600 feet from shore; water 10 to 16 inches deep; bottom hard, rocky; 1 branch.

Brook's description of this variety is satisfactory, but as additional descriptions of forms not generally known are desirable, I am publishing that of the Murray Island specimens. One of the principal variations is in the amount of crowding and in the size of the radial corallites. A specimen 1,400 feet from shore has corallites slightly less than 1 mm. apart and on the lower portion of the branch the diameter is often only 0.5 mm. A specimen 1,600 feet from shore has, on the lower part of the stem, radial calices up to 1.5 mm. apart; margins slightly elevated, somewhat tumid around the base; two cycles of septa, the secondaries small or rudimentary; and an irregularly shaped, slightly prominent, plug-like columella.

Distribution.—Rocky, Thursday, and Palm Islands, Great Barrier Reef; Torres Strait.

Acropora (Eumadrepora) haimei (Milne Edwards).

Plate 70, figures 3, 3*a*, 3*b*, specimen from Murray Island.

1860. *Madrepora haimei* Milne Edwards, Hist. nat. Corall., vol. 3, p. 151.
1893. *Madrepora haimei* Brook, Cat. Genus Madrepora, p. 77.
1907. *Acropora haimei* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 51, plate 16, figs. 45–48.

A description of a specimen of this species from Murray Island follows:

Corallum cespitose, rising from an incrusting base. Height about 10 cm.; greatest spread of branches nearly 16 cm. Length of branches between 60 and 65 mm.; diameter at base 9 to 12 mm.; the main branches subdivide 3 or 4 times between the base and summit. Sets of branches from 12 to 30 mm. apart. Branchlets up to nearly 40 mm. long, basal diameter 7 mm. The following are measurements of branchlets:

Measurements of branchlets af Acropora haimei.

Branchlet No.	Length.	Basal diameter.	Axial corallites.	
			Diameter.	Exsert.
	mm.	*mm.*	*mm.*	*mm.*
1	22.0	5.5	2.5	1.5
2	26.0	6.5	3.0	1.75
3	35.0	6.5	3.0	1 5
4	36.5	7.5	2.75	1.0
5	39.5	7 0	2.75	1.5
6	45.0	8.0	2.50	1.5

Axial corallites, dimensions as given in table. Walls, thickness somewhat less than one-third the corallite diameter; texture relatively dense; outer surface with distinct, plate-like costules, with synapticulæ in the intercostular spaces. Septa in two well-developed cycles; the primaries may meet deep down; secondaries smaller but distinct.

Radial corallites unequal, proliferous and non-proliferous, protuberant and immersed or subimmersed. The non-proliferous protuberant corallites attain their full size near the branch ends, within about 5 mm., where they are spreading at right angles or ascend slightly; length 2.5 to 3 mm.; diameter 2 mm.; with a thicker lower wall, a poorly developed upper wall, and a nariform aperture. Lower down the outer end of the lower wall may curve upward, producing a form like half a canoe. Texture reticulate but rather dense; costules distinct, plate-like. Lower still the corallites decrease in prominence, and are nariform, appressed tubular, or labellate, merging into immersed corallites. Directive septa distinct, other primaries small, secondaries inconspicuous or absent. The protuberant corallites grade into tubular, proliferous corallites 4 mm. long and 2.5 mm. in diameter, which in their turn grade into branchlets. In these the primary septa are well developed and often a few secondaries are distinct. Some small immersed or subimmersed corallites scattered between the prominent ones.

Cœnenchyma echinulate and costulate, becomes rather dense.

Station, Murray Island.—Southeast reef, line I, 800 feet from shore; depth, about 11 inches; bottom, broken coral.

Distribution.—Red Sea; Indian Ocean; Fiji Islands (Brook and others); Great Barrier Reef.

The growth-form of this specimen is very similar to that represented by von Marenzeller's figure 47 (plate 16). One of the striking features of the species is the prominence of the radial corallites almost to the tips of the branches. This is the first record of the species from the Great Barrier Reef.

Acropora (Eumadrepora) haimei (Milne Edwards) var.

Plate 66, figures 4, 5, specimen from Murray Island.

The following is a description of specimens of *Acropora haimei* variety:

Corallum loosely branching; three branchlets radiate from same level on main stem. Dimensions as follows:

Measurements of main stem and branches of Acropora haimei var.

	Length.	Diameter of base.	Diameter axial corallites.
	mm.	*mm.*	*mm.*
Main stem.....	122	15.5	3.5
Branch 1......	70	13	about 3
2......	about 66	10.5	(broken)
3......	19.5	8.5	2.75

The smallest branch makes an angle of about 60° with the stem; the largest has an initial angle of about 60°, but later points more nearly upward, curving so as to make an angle of 45° to 50°.

Axial corallites, diameter from 2.75 to 3.5 mm.; aperture 1.25 mm. in diameter; protuberant about 1.5 mm.; walls porous, radiately reticulate, 1 mm. or somewhat more thick; outer surface longitudinally costulate. Costules as narrow plates, with perforations in the interspaces. Septa in two complete cycles; the directives meeting deep down in the calice; the other primaries extend a little more than halfway to the axis; the secondaries well developed, length about one-third that of a radius.

Radial corallites, both protuberant and immersed. Of the protuberant, one is occasionally proliferous; angle with surface of branch about 45°; somewhat taller near the ends of the branches, up to 3 mm.; diameter about 2 mm.; nearly the same from base to aperture. Outer wall thicker than inner, with rather prominent plate-like costules, perforate in the furrows, margin not rounded or constricted, except near the base of the stem, where there are some nariform corallites. Inner wall thin and slightly developed, except in rare instances, but appears always to be distinct; the usual height is probably about one-third that of the upper side of the corallite. The corallites are very slightly or not at all laterally compressed. Apertures dimidiate (see Dana, plate 30, fig. 7*a*). The direc-

tive septa are wide and often either meet or nearly meet deep down in the calice; the outer directive is on an average more developed than the inner; the other primaries present, but are short and rather inconspicuous; a complete cycle of inconspicuous, rudimentary secondaries can usually be distinguished. On older parts of the corallum, two cycles are clearly developed; the outer wall is thickened and curved toward the upper directive septum. Immersed corallites, about 0.75 mm. in diameter, occur between the bases of the protuberant ones. Two cycles of septa, the second very small, can frequently be distinguished in these.

Cœnenchyma flaky, granulate-costulate, with perforations between the costules.

Station, Murray Island.—Southeast reef, line I, 1,400 feet from shore; depth 14 to 15 inches; bottom rocky, broken coral.

Two specimens, both only fragments, have greatly perplexed me, but structurally they are so similar to *A. haimei* that I am referring them to that species. Comparison of the figures and the descriptions show their similarity. The variant has thicker branches, a more arborescent growth-form, and the radial corallites are rarely or not at all compressed laterally. Near its base, however, the lower wall of the radial corallites is thickened, and is curved toward the upper directive, similar to the condition in *A. haimei.*

Acropora (Eumadrepora) decipiens (Brook).

Plate 67, figures 2, *2a*, *2b*, specimens from Murray Island.

1893. *Madrepora decipiens* Brook, Cat. Genus Madrepora, p. 51, plate 14, figs. B, C, D.

The following is a description of a specimen of *Acropora decipiens* from Murray Island:

Corallum with an expanding base, 137 by 165 mm. in diameter, above which rise stout stems. Lesser basal diameter of the stems between 25 and 30 mm., greater basal diameter up to nearly 35 mm. The branches tend to spread laterally; some may bend downward and fuse to the basal expansion, and there is considerable anastomosis, both with a tendency toward plate formation at the bases and with cross-fusions nearer the periphery. The horizontal diameters of the colony are 230 by 287 mm.; height about 90 mm. Diameter of a branch from 12 to 17 mm. about 50 mm. from the end. The cross-section is subcircular or somewhat compressed radially.

Axial corallites rounded, short conical, or protuberant with plane margins; diameter from 3 to 4 mm. across the aperture; exsert, about 2 mm.; walls thick, reticular, porous or considerably compacted, externally costulate; 2 well-developed cycles of septa, the primaries nearly meeting, secondaries about half as long. The form of the axial corallite appears to be largely determined by environmental condition. The specimen here described is from the Lithothamnion ridge, where the water is relatively rough and perhaps there is more or less detritus in suspension. Whatever may be the cause, the rounded and short conical corallites are mostly on the upper surface, while the protuberant, subcylindrical axial corallites with flattish margins are around the periphery.

Radial corallites strikingly unequal in size; on the lower surface except near the periphery immersed or subimmersed; diameter about 1 mm., about 1 mm. apart; as the branch ends are approached, the lower lips of some corallites become more prominent, with resulting short labellate, gutter-shaped, dimidiate, and nariform apertures, maximum length about 3.25 mm. On the upper surface are small immersed or subimmersed corallites; many small corallites have a thin, spout-shaped lower wall, diameter 1 mm. or less. The larger corallites range in height from 3 to 5 mm.; in diameter, from 1.5 by 2 mm. to 2.5 by 3 mm.; their distance apart about 1 to 3 mm. On the sides of the larger corallites, especially near the base, are small corallites with thin, produced lower walls and entirely without upper walls. Except near the branch ends, where they are slightly ascending, the large corallites stand perpendicular to the branch surface. The form ranges from dimidiate through nariform to tubo-nariform or tubular with an oblique aperture. The lateral compression is considerable; in many calices the outline of the aperture is narrow elliptical. The outer wall is rather thick, at first porous; later it becomes compact, but synapitculæ may still be recognized between the costules; it may slightly recurve or slightly incurve at the margin. The

costules are prominent and plate-like. The edge is at first acute, but with subsequent thickening it becomes obtuse or rounded. The inner wall is absent, thin, or considerably developed, but the aperture remains oblique. Usually, unless the corallites are greatly compressed, 2 cycles of septa are present, the primaries the more prominent, the outer directive large; secondaries small, usually rudimentary.

Cœnenchyma near the branch ends costulate, reticulate, and echinulate, subsequently becomes almost solid.

Station, Murray Island.—Southeast reef, Lithothamnion ridge, 1,725 to 1,850 feet from shore; from tide pools and crevices, where it was constantly swept by breakers at low tide.

Distribution.—Great Barrier Reef.

Brook's figures of his *M. decipiens* are so poor that no details of the corallites, only the growth-form, can be made out from them, and he does not sufficiently describe the transverse outline of the corallites. However, it seems improbable that the specimen I am identifying as *M. decipiens* could be anything else.

Acropora (Eumadrepora) abrotanoides (Lamarck).

Plate 68, figures 1, 1*a*, 2, specimens from Murray Island.

1893. *Madrepora abrotanoides* Brook, Cat. Genus Madrepora, p. 56.

I am referring three small, immature specimens, two of which are figured, to this species. In general aspect they closely resemble *A. decipiens*, but a larger number of the proliferous corallites form short twigs; the inner walls of the protuberant radial corallites are better developed, becoming "ultimately similar to the axial ones,"[1] and the septa of the radial corallites are much better developed. They are close to *Acropora danai* (M. Edw. and H.) (type in U.S. Nat. Mus., No. 303), but the radial corallites of the latter have very perforate walls, of lace-like structure and texture, whereas in the specimens I am referring to *A. abrotanoides* the walls are relatively compact, as in *A. decipiens.*

Station, Murray Island.—Southeast reef, line I, 1,200 feet from shore; depth 12 to 16 inches; bottom rocky.

Distribution.—Tahiti; Great Barrier Reef; Singapore.

Acropora (Eumadrepora) pharaonis (Milne Edwards).

Plate 69, figures 1, 2, 3, 3*a*, 4, 4*a*, 5; plate 70, figures 1, 2, 2*a*, specimens from Cocos-Keeling Islands.

1860. *Madrepora pharaonis* Milne Edwards, Hist. nat. Corall., vol. 3, p. 143.
1893. *Madrepora pharaonis* Brook, Cat. Genus Madrepora, p. 58.
1906. *Acropora pharaonis* von Marenzeller, Denksch., k. k. Akad. Wiss. Wien, vol. 80, p. 35, plates 4–8, figs. 10-18; plate 9, figs. 10*a*-17*a*.
1907. *Madrepora pulchra* Wood Jones, Proc. Zool. Soc. London for 1907, p. 534, text-figs. 155, 156; p. 543, text-fig. 160; p. 544, text-fig. 161; plate 27, fig. 2*a* (both figures), fig. 2*b* (left-hand figure).
1910. *Madrepora* Wood Jones, Coral and Atolls, p. 75, text-fig. 13; p. 89, text-fig. 24*a* (both figures), 24*b* (left-hand figure), p. 113, text-figs. 40, 41.
1910. *Madrepora pulchra* Wood Jones, Coral and Atolls, p. 96, text-figs. 29, 30.
1911. *Madrepora pharaonis* Gravier, Ann. Inst. Océanogr., vol. 2, fasc. 3, p. 73, plate 10, figs. 42, 43.

Brook published the following descriptions of Milne Edwards's types of *Madrepora pharaonis* and *M. pustulosa:*

"Type. Corallum arborescent with stout branches, between which occasional fusions occur, recalling the habit of *M. crassa.* Branches 2.3 cm. thick, 30 cm. long, laxly subdivided. Axial corallites 2.5 mm. diameter, 1.5 mm. exsert; septa in two cycles, with directives scarcely broader than the other primaries. Radial corallites chiefly immersed, with a few labellate, but scattered between are tubular ones almost at right angles; about 5 are distributed to each 2.5 cm.; these are 3 mm. long and 2 mm. diameter, and mostly bear a rosette of short labellate corallites. The tubular proliferous corallites have appar-

[1]Brook, *op. sup. cit.*

ently only 6 septa, the directive much broader than the others. In the immersed corallites the septa are more nearly equal. Corallum moderately porous; surface reticulate and echinulate; wall striate and fragile. (The specimen appears worn.)

"Another specimen in the Paris Museum, from the same locality, is labelled *M. pustulosa*, and if this should prove to be the type of M.-Edwards's species it is certainly not distinct from the above. M.-Edwards, however, gives Seychelles as the habitat of his *M. pustulosa*; but so far as I can ascertain there is no specimen of the species from that locality in the collection, and the description given agrees fairly well with this specimen. The specimen here referred to is a fine well-preserved form with the following characters: Main branches 3 cm. thick, much divided, with numerous spreading and tapering branchlets. Axial corallites 2.5 to 3 mm. diameter, 3 mm. exsert. Radial corallites simple, tubular with oblique aperture, of variable length up to 4 mm. and 1.5 mm. diameter, at an angle varying from 60° to 80°, with short, nariform, labellate and immersed ones between. This is the arrangement on the younger branches; in other parts the tubular corallites become elongate and proliferous, up to 2.5 cm. in length, 5 mm. diameter at the base, with tubo-labellate bud-corallites at an angle of about 60°; the majority of the proliferations are, however, only from 5 to 7 mm. long. This specimen appears to me to give the real characters of the species better than the type.

"A third specimen of enormous size, over 1 m. diameter, shows the proliferations still more elongate, forming branchlets averaging 15 mm. in length. All three specimens are from the Red Sea and were collected by Botta in 1837.

"The moderate variation in size of the axial corallites and the variation in length of the proliferous corallites or branchlets, according to age, have probably led to this species being described under several names. It is significant that all the types of all the forms (?*M. pustulosa* Edw. and H.) come from the Red Sea.

"Indian Ocean; Red Sea; Keeling Island."

Dr. Wood Jones has brought from Cocos-Keeling fragments of an interesting series of specimens, which will be described serially:

Specimen No. 1 (plate 69, fig. 2):

A branch, 137 mm. long; diameter of lower end, 12 mm.; diameter of axial corallite, 3.75 mm.; 3 branchlets given off about 36 mm. below tip. Axial corallite with thick costulate walls and 2 well-developed cycles of septa. Proliferous corallites perpendicular to surface of branch confined to one side; from 3 mm. up to 8.5 mm. tall; diameter of axial corallite of the proliferations from 2 to 3.25 mm.; lateral corallites labellate or tubo-labellate; 2 cycles of septa with prominent directives. The other protuberant radial corallites nearly perpendicular to the surface of the branch, tubular, with the inner wall shorter than the outer, or nariform; height, 1.5 to 3 mm.; diameter about 2 mm.; distance apart, 2 to 2.5 mm.; wall thick, porous, apertures elliptical, but not greatly compressed; 2 cycles of septa, directives prominent, secondaries small or rudimentary; walls costulate, perforate. Immersed corallites usually show 2 cycles of septa. Cœnenchyma costulate, granulate, perforate, flaky.

Regarding this specimen Dr. Wood Jones says: "Fragment of a colony growing in a site in which much sediment is carried in the water."

Specimens No. 2 (plate 69, figs. 3, 3a):

Two specimens experimented with by Dr. Wood Jones in studying the repair of injury to corals. The larger specimen is 80 mm. long; diameter of lower end, 25 by 28 mm.; of upper end, about 21 mm. These differ from No. 1 chiefly by having the corallites so crowded that over large areas the walls of adjacent corallites touch. There are many labellate corallites between the protuberant ones. The texture of the walls is more delicately reticulate than in No. 1.

Specimen No. 3:

This is another of Dr. Wood Jones repair specimens. It is similar to No. 2, except that there are no protuberant corallites; all are crowded and tubo-labellate or immersed.

Specimen No. 4:

This specimen is one obtained by Dr. Wood Jones in the still water of the lagoon and twice figured by him.[1] It is a branch about 81 mm. long; diameter of lower end, 13 by

[1]Proc. Zool. Soc. London for 1907, plate 27, figure 2*b* (left-hand figure). Coral and Atolls, p. 84, figure 24*b* (left-hand figure), 1910. The right-hand one of the two figures represented by "*b*" is another species, *Acropora pulchra* (Brook).

15 mm.; of axial corallite, which is damaged, about 3.5 mm. This is a remarkably interesting specimen, as on its lower 55 mm. it combines the characters of specimens Nos. 2 and 3, and over a small area has the character of forma *arabica*, while on its distal end it has the characters of the set of specimens next to be described. Some of the corallites near the tip are dimidiate. This specimen will not be more fully described, as the characters of its distal portion will be given under the next specimen.

Specimens No. 5 (plate 69, figs. 1, 4, 4a, 5):

Two of this set of branches have been figured by Dr. Wood Jones.[1]

Corallum cespitose, attached by a narrow base. Height about 21.5 cm.; horizontal diameter, about 28 cm.

Dimensions of branches of Acropora pharaonis.

No.	Length.	Diameter of lower end.	Diameter of axial corallite.	Exsertness of axial corallites.	Branchlets.	
					Present.	None.
	mm.	*mm.*	*mm.*	*mm.*		
1	36.5	9.0	3.75	1.5	..	×
2	35.0	9.0	3.5	2.0	×	..
3	44.0	9.0	3.5	1.5	..	×
4	55.0	9.5	2.5×3.5	2.25	..	×
5	54.0	about 9.0	3.5	....	×	..
6	56.5	9.0	3.25	1.5	×	..
7	62.5	9.0	3.5	....	×	..
8	63.5	10.25	4.0	1.5	×	
[1]9	64.5	10.0	3.6	2.5	×	..
10	64.0	10.75	3.5	1.25	..	×
11	70.5	11.5×13.0	3.5	1.5	×	..
[2]12	78.5	11.75	3.5	2.5	×	..

[1]Only 1 branchlet, 45 mm. below tip of branch; plate 69, figure 5.
[2]Plate 69, figures 4, 4*a*.

The diameter of the aperture of the axial corallites ranges from about 0.9 mm. to a little more than 1 mm. The walls are thick, about 1 mm., porous, reticulate, and friable, with plate-like costules on the outside. Two well-developed cycles of septa, the secondaries smaller than the primaries.

Radial corallites, both protuberant and immersed. The protuberant corallites of two kinds, proliferous and non-proliferous. The proliferous corallites seem especially well developed on the outer sides of branches; their distribution irregular; they are inclined at an angle of about 45° to the surface of the branch; range up to 5.5 mm. long (measured along the lower side); outline very slightly elliptical; diameter up to 3 mm.; 2 cycles of septa, the secondaries the shorter; labellate corallites near the bases of the branches. The non-proliferous, protuberant corallites vary according to the position on the branch or branchlet. On the outer surfaces near the tips they ascend at an angle of about 45° and are up to 3 mm. long (measured along the lower side); 1.5 mm. in diameter, about 1 mm. apart; the outer wall is thick and reticulate, and costulate with intercostular pores; inner wall scarcely developed, short, thin; aperture dimidiate or nariform, subcircular or very slightly compressed; 6 primary septa, the directives prominent, the secondaries rudimentary or entirely inconspicuous. On the inner sides of branches the corallites are shorter, about 2 mm.; somewhat smaller, more uniform is size, more evenly distributed, and labellate.

Cœnenchyma costulate and echinulate.

Regarding this set of pieces, Dr. Wood Jones says:

"Fragments from different colonies of the most abundant form growing in the barrier pools where there is a moderate degree of broken water at some states of the tide. The colonies grow to a great size and every modification in the degree of raising of the corallites is seen, one colony often supplying branches so different in their minute characters that they differ more widely than do many so-called species. The color is yellowish or brownish in some colonies; the zooid is pale."

[1]Proc. Zool. Soc. London for 1907, plate 17, figure 2*a*. Coral and Atolls, p. 89, figure 24*a*, 1910.

The foregoing descriptions have been drawn up in such a way that they, taken in connection with the figures on plate 69, will, I trust, make it obvious that the series of specimens all belong to one species. The variation is greater than has been emphasized, for there are areas on specimens 2, 3, and 4 in which there are no protuberant corallites, and the condition is the same as that represented by *A. arabica*. An excellent specimen of *A. pharaonis* in the U. S. National Museum collected by Dr. W. L. Abbott in the western Indian Ocean, probably at Aldabra, is almost a duplicate of von Marenzeller's "fächerförmige, reich verästelte, floride Kolonie" (his plate 4, fig. 10). The difference between it and the Cocos-Keeling specimens is so great that it scarcely seems possible to refer them to the same species, but at present I see no other course; they are similar in the character of their proliferous corallites.

Von Marenzeller devotes 4 quarto pages and 6 plates to this species in his account of the *Pola* reef-corals, and places *M. pharaonis*, *M. pustulosa*, and *M. arabica* of Milne Edwards, *M. scandens*, *M. spinulosa*, *M. microcyathus*, and *M. subtilis* of Klunzinger, and *M. laxa* of Haeckel (*non* Lamarck) in its synonymy.[1]

"Die Kolonie von *A. pharaonis* lässt sich stets auf mehrere primäre Hauptstämme zurückführen, aber deren anordnung, die Richtung ihres Wachstums und ihr Verhalten zueinander beeinflussen den Habitus in ausserordentlicher Weise. Gewöhnlich verschmelzen die Hauptstämme an der Basis. Sie wachsen dann entweder gerade oder wenig schief in die Höhe, nach allen Richtungen einige Äste und kurze Triebe entwickelnd, oder sie breiten sich allseitig horizontal oder etwas ansteigend aus; die Äste anastomosieren vielfach netzartig untereinander oder verwachsen völlig. Es entstehen so grosse starke Platten mit einem kurzen zentralen Sockel oder vasen- oder halbvasenförmige Stöcke oder die Stämme und ihre Verzweigungen breiten sich in einer Ebene, also nur einseitig aus; die Kolonie ist plattenförmig, der Sockel ganz exzentrisch; er bleibt zumeist bei dem Abbrechen der Kolonie am Riff zurück, ist abgestorben oder von fremden Bildungen überdeckt.

* * * * * * * * *

"Massgebend für die Zusammenfassung von Korallen, die einen so verschiedenen Habitus besitzen, wie ihn die beigegebenen Abbildungen zeigen, war auch in diesem Falle die Feststellung eines Grund-charakters, der den Kelchen entnommen wurde, und die Ausschaltung von Abweichungen, die nur Wachstumserscheinungen sind und nicht arttrennende Merkmale. Was Klunzinger über die Kelche von *M. scandens* sagt: teils röhrenförmig, teils gespalten, meist ohne Innenrand, dillen-, rinnen-, lippen-, schuppenförmig, zugespitzt, gelippt u. s. w., weist deutlich darauf hin, dass die Entwicklung der Kelche solcher Exemplare in einem regen Flusse begriffen ist, Unfertiges neben Fertigem besteht. Die Unterwand und die Seitenwände der Kelche zeigen wie bei *A. corymbosa* die verschiedensten Grade der Ausbildung. Es ist ganz gleichgültig, ob die heranwachsenden Kelche noch gespalten oder schon röhrenförmig sind. Auch an jenen können sich bei lebhaftem Triebe Seitenkelche entwickeln oder diese zeigen noch spät, wenn sie bereits lang und dick geworden sind, die Abschrägung, die die Abstammung von der ursprünglichen Dillenform verrät. Das Ziel ist, wie der Vergleich von zahlreichen Exemplaren der verschiedensten Fundorte und des divergentesten Habitus zeigt, die Bildung von Sprossenkelchen, deren Zahl und Länge wechseln. Relativ wenige von ihnen wachsen zu Zweigen aus. Bei unter günstigen Verhältnissen üppig wachsenden Kolonien sind diese Zentren der Prolifikation überall zu sehen und heben sich mit ihren grossen Axialkelchen charakteristisch ab. Je grösser der Kontrast zwischen ihnen und den dazwischen liegenden unentwickelten Kelchen ist, umso unruhiger and ungleichmässiger wird der Eindruck, den die Oberfläche der Kolonie macht. Bildungsexzess and Bildungsmangel erzeugen neue Bilder. Durchaus eigentümlich wird das Aussehen, wenn alle Kelche die gleichmässige Tendenz haben, länger zu werden oder sich zu verkürzen. Auch in diesen Fällen wird man die Sprossenkelche noch finden, allein im ersten verlieren sie ihre Präponderanz und im zweiten werden neu entstehende unansehnlich. Ein besonderer und konstanter Charakter ist die bereits von Klunzinger hervorgehobene wechselnde Richtung der Kelchmündung nach oben, unten und seitlich. Die bedeutenden Veränderungen, die diese Art zeigt, hängen, zum Teil wenigstens, von dem Standpunkte am Riffe ab, den die Kolonie einnimmt.

[1] *Op. cit.*, pp. 36, 37.

"Es kennzeichnen sich die grossen massiven Platten (eigentliche *M. pharaonis* E. H.) oder auch die kleineren massiven Vasen oder die strauchartigen Kolonien von Zylinderform mit oft sehr reduzierten Kelchen (*M. arabica* E. H.) als Widerstandsformen des bewegten seichteren Wassers, während die zarteren, ast- und kelchreichen, floriden Formen die ruhige Tiefe bewohnen. In unserer Sammlung sind Zwischenglieder vorhanden und eigentlich trägt jede in Habitus noch so sehr divergierende Form an ihren jüngsten Trieben den Stempel der Zusammengehörigkeit, aber es ist noch keineswegs erwiesen, dass die Art an derselben Lokalität die zuvor erwähnten Formen ausbildet. Für Kosier ist es nach den ausdrücklichen Bemerkungen von Klunzinger sicher, dass sie daselbst nur in der Tiefe vorkommt. Ich habe weder von dort noch von Tor oder Jidda Stöcke gesehen, die den von Massawa (Taf. 5, Fig. 13; Taf. 7, Fign. 16, 17) glichen (typische *M. pharaonis* von E. H.), die ich als Form des seichten Wassers auffasse. Klunzinger fand bei Kosier hauptsächlich die Form, die er *M. scandens* nannte. Seine nur in wenigen Stücken wahrscheinlich aus gröserer Tiefe heraufgeangelte Form der *M. scandens*.

"Die Beschaffenheit der Kelche der Unterseite der Kolonien von *A. pharaonis* steht immer im Verhältniss zu der Ausbildung der Kelche der oberen Fläche der Aeste. Man kann daher je nachdem nur Porenkelche oder Kelche mit halbwegs entwickelter Unterwand oder selbst Röhrenkelche und Sprossenkelche finden.

"An *A. pharaonis* zeigt sich wieder, wie trügerisch und unzuverlässig die Merkmale sind, nach welchen man die Arten der Gattung in Gruppen zu bringen versuchte. Klunzinger, der die Axialkelche berücksichtigte musste die vier Formen, die er als Arten unterschied, auf zwei Gruppen verteilen. Wir finden die kleinkelchige Plattenform (*microcyathus*) nebst der strauchartigen, allseitig kurze Sprossen mit reduzierten Kelchen entwickelnden *M. spinulosa* in der Gruppe *Cb*, dagegen *M. scandens* und die atrophische *M. subtilis* in der Gruppe *Da*.

"Brook, der die Identität von *M. microcyathus* mit *M. pharaonis* und der *M. spinulosa* mit *M. arabica* E. H. richtig erkannte, hält *M. subtilis* als eigene Art aufrecht und betrachtet *M. scandens* als Varietät der *M. ehrenbergi* E. H., womit ich mich nach Untersuchung des Originalexemplares im Pariser Pflanzengarten nicht einverstanden erklären kann. Diese vermeintlichen vier Arten verteilt er auf zwei Untergattungen. *M. ehrenbergi* E. H. steht in der Gruppe *E*, *M. pharaonis* in der Gruppe *G* der Untergattung *Eumadrepora*. *M. arabica* E. H. und *M. subtilis* Klzgr. werden der Untergattung *Odontocyathus* zugeteilt."

A comparison of the figures on plate 69 of the present paper with the natural-size views on von Marenzeller's plate 9, especially figures 14*a* and 17*a*, will, I believe, lead to the conclusion that the Cocos-Keeling specimens are nearly related to the growth-form of the species represented by his figure 17, plate 7. Plate 69, figure 2, resembles the variant designated *microcyathus* by Klunzinger, except that its corallites are larger (see Klunzinger's plate 3, fig. 3, and plate 4, fig. 19).

Notwithstanding the attempts of Brook, von Marenzeller, Gravier, and the one here made to describe the variations of this protean coral, I feel that it has not yet received adequate attention.

Distribution.—Red Sea; western Indian Ocean (probably Aldabra); Cocos-Keeling Islands.

Acropora pharaonis forma arabica (Milne Edwards).

Plate 70, figures 2, 2*a*, specimen from Cocos-Keeling Islands.

1860. *Madrepora arabica* Milne Edwards, Hist. nat. Corall., vol. 3, p. 145.
1892. *Madrepora arabica* Brook, Cat. Genus Madrepora, p. 66.
1906. *Acropora pharaonis* (*arabica* mentioned as a form) von Marenzeller, Denksch. k. k. Akad. Wiss Wien, vol. 80, pp. 35-39, plate 8, fig. 18.
1907. *Madrepora pulchra* Wood Jones, Proc. Zool. Soc. London for 1907, p. 534, text-fig. 155.
1910. *Madrepora pulchra* Wood Jones, Coral and Atolls, p. 46, text-fig. 29.

This form has been referred to in the preceding description of *A. pharaonis*, in both the quotation from von Marenzeller and in the account of the specimens from Cocos-Keeling Islands. It is considered a variant of *A. pharaonis*, in which there are no protuberant corallites, and the apical corallites are greatly reduced

in size. On the same specimen of *A. pharaonis* there are areas in which the calicular margins are protuberant and other areas in which the corallite walls do not project beyond the cœnenchymal surface. Plate 70, figure 1, represents a colony in which the calices are only slightly protuberant. This form of colony is represented by or intergrades with specimen No. 3, described on page 167. On one side of the latter specimen a large part of surface has calices similar to those represented by plate 70, figures 2 and 2*a*.

Dr. Wood Jones says regarding the specimen illustrated by plate 70, figures 2 and 2*a*:

"Fragments of a colony showing the extreme degree of flattening of the corallites due to the absence of any sediment in the water of its habitat. Whole colonies of this facies are found, in which the corallites are flattened and the growths are characteristic. The ends of the branches are rounded and apical zooid is not marked. Occasionally branches of this facies are found on colonies of other facies, and in all old colonies the older branches tend to assume this form unless sediment is abundant."

Von Marenzeller considers forma *arabica* as "Widerstandsformen des bewegten seichteren Wassers" (see quotation on page 170).

Acropora (Polystachis) corymbosa (Lamarck).

Plate 67, figure 1, specimen from Cocos-Keeling Island.

1893. *Madrepora corymbosa* Brook, Cat. Genus Madrepora, p. 97.
1906. *Acropora corymbosa* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 32, plate 1; plate 2, figs. 1–8; plate 3, figs. 1*a*–8*a*, 9.
1910. *Madrepora* F. Wood Jones, Coral and Atolls, plate 3, opposite p. 76.

The following is a description of a specimen of this species from Cocos-Keeling Islands:

Corallum fan-shaped, with branchlets projecting upward on the upper surface except near and around the margin. Branchlets up to about 40 mm. long, simple or bifurcating, some trifurcating, radially compressed. Diameter of base of a simple branchlet 5 mm.; by fusion of their bases plates 22 mm. wide may be formed, thickness of such a plate 5 mm.

Axial corallites, 1.5 mm. to 2 mm. in diameter; project about 1.5 mm.; wall porous, reticulate, radial costules well developed, thickness about one-third the diameter of the corallites; 6 primary septa well developed, the directives usually meet in the axis; rudimentary secondaries frequently but not persistently distinguishable.

Radial corallites ascending, appressed, tubo-labellate; near the tips of the branchlets the outer margin is much taller than the inner and sometimes curves upward; walls thin, delicate, perforate, costulate. Farther down on the branchlets, the wall on the outside may not project higher than on the inside. Diameter, about 1.25 mm.; length (on outside), up to 3 mm. Aperture elliptical. Six primary septa usually distinct, directives conspicuous; secondaries rudimentary, obscure, or absent. The corallites become less prominent toward the bases of the branchlets, and on the main branches are subimmersed or immersed.

Cœnenchyma perforate, costulate, and echinulate. On the branchlets it is a very porous lax reticulum.

Habitat, etc., Cocos-Keeling Islands.—Dr. F. Wood Jones furnishes the following notes:

"Fragments of a particularly fine colony, the only one of precisely this kind found. It formed the summit of a composite mass in the inlet between Pulu Pasir and Pulu Tikus. Many of the great fan-shaped branches measured 5 to 6 feet across. The fan-shape was well developed, but the plate formation was not so complete as in colonies seen on the barrier reef. Only at its base was there any marked anastomosis of branches. The color while alive was brown; the distal ends of the branches were white or pale yellow."

Dr. Fred Baker has sent to the U. S. National Museum a specimen which he collected at Fanning Island and which I am referring to this species. It is a fan-shaped frond with branches projecting upward on its upper surface. Von Maren-

zeller's figures 7 and 7*a* represent the characters of the specimen fairly well. Some of the branchlets are similar to his figure 6*a*.

Distribution.—According to Brook it is "Red Sea; Rodriguez; Ramesvaram; China Sea; New Holland; Great Barrier Reef; Fiji; Tahiti." I can add Makemo, Paumotus (*Albatross*, 1899–1900), and Fanning Island (Dr. Fred Baker). This is a very widely distributed species.

Acropora (Polystachis) pectinata (Brook).

Plate 71, figures 1, 1*a*, 1*b*, 1*c*, 2, specimens from Murray Island.

1893. *Madrepora pectinata* Brook, Cat. Genus Madrepora, p. 95, plate 27, figs. D, E.

Dr. Mayer collected two specimens, which I refer to this species:

Specimen No. 1, plate 71, figs. 1, 1a, 1b, 1c:

Corallum attached to dead coral stems by a basal expansion, above the central portion of which the principal branches extend more or less horizontally, while the branchlets rise to about the same level; form corymbose. Diameter of basal expansion about 50 by 70 mm.; diameter of upper surface of corallum about 95 by 130 mm.; height of corallum, between 55 and 60 mm. Main branches somewhat compressed radially, lesser diameter about 6 mm.; considerable lateral fusion of branchlets, but this small specimen has not formed plates.

The lower surface of the branches with some protuberant corallites, up to 2.5 mm. tall, diameter up to 2 mm.; other corallites on the under surface are immersed, or the inner wall may be poorly developed or absent, the outer wall not often as much as 2 mm. long. On the basal expansion the wall away from the growing edge is usually elevated as a lip and considerably thickened.

On the upper surface the branchlets occur singly or in groups of twos or threes. They are erect in the central area, outside of which they are inclined but curve upward. Height from about 13 to nearly 20 mm.; basal diameter 4 to 6 mm.; apices 4 to 7 mm. apart.

Axial corallites, average about 1.5 mm. in diameter, exsert up to 1.25 mm., usually less; thickness of walls less than the length of the calicular radius. Primary septa distinct, but a directive only sometimes reaches the axis; secondaries rudimentary or absent.

Radial corallites spreading; decrease in prominence inferiorly; outer surface costulate. Outer wall: length, about 1.5 mm.; width of tip 1.5 mm.; edge thin and friable. Inner wall usually not developed. Apertures labellate; outer lip in plan usually has a rounded outline; rarely are the apertures somewhat dimidiate. Viewed in profile the plane of the apertural margins slightly ascends from its inner margin outward or is nearly perpendicular to the surface of the branch, but in no instance was it flattened or depressed. The directive septa are usually distinguishable; but the other septa are usually rudimentary, vestiges of secondaries can sometimes be recognized.

On the central area between the erect branchlets all the corallites are immersed.

Cœnenchyma rather porous, delicately costulate and spinulose.

Station, Murray Island: Line I, southeast reef, 800 feet from shore; depth 10 inches; bottom, broken coral.

Specimen No. 2, plate 71, fig. 2:

This is a marginal fragment of corallum which had assumed the horizontal-plate growth-form. Its inner edge is 24 mm. thick. The figure (plate 71, fig. 2) adequately illustrates it. The structural characters are similar to those of specimen No. 1.

Station, Murray Island: Line I, southeast reef, 1,600 feet from shore; depth, 10 inches; bottom hard, rocky.

Distribution.—Great Barrier Reef and Torres Straits.

Acropora (Lepidocyathus) spicifera (Dana).

Plate 68, figures 3, 3*a*, 3*b*, specimen from Cocos-Keeling Islands.

1846. *Madrepora spicifera* Dana, U. S. Expl. Exped., Zooph., p. 443, plate 33, figs. 4, 4*a*, 4*b*, 5.
1893. *Madrepora spicifera* Brook, Cat. Genus Madrepora, p. 92.

The following is a description of a specimen collected by Dr. Wood Jones:

The corallum "consists of low spreading branches; it is 6 to 9 inches in diameter and 2 or 3 feet in circumference. The branches extend horizontally, but only in places do they

anastomose to form plates."[1] Branchlets are directed upward on the upper surface, except near and on the periphery, where they are at first horizontal and then curve upward. Lower surface without branchlets, and with only immersed or subimmersed corallites, except on the underside of the peripheral branchlets. A peripheral fragment of a colony has a radial length of 76 mm.; inner end of branch has diameters of 10 by 12 mm.; the radial compression is rather slight. Branchlets simple or bifurcate; height 12 to 15 mm.; diameter of bases, 4 to 5 mm.

Axial corallites, diameter 2 to 3 mm.; very slightly protuberant, up to about 1.5 mm.; walls, thickness about one-quarter the corallite diameter, composed of costules and concentric synapticulæ; texture loose and friable; costules on outer surface thin and plate-like; septa in 2 well-developed cycles, primaries nearly meeting in the axis; secondaries about half as long; occasionally more than 12 septa.

Radial corallites immersed or subimmersed on the main branches, diameter 0.6 mm. to about 1 mm., distance apart slightly greater than the diameter; on the branchlets, except at their bases, prominent and crowded; length on outer surface about 2 mm.; diameter at base about 1 mm.; at tip, about 1.75 mm. *The outer wall flares out at the calicular margin and is more or less flattened above;* it is reticulate, porous, and costulate; the edge is delicate and friable, but somewhat thickened. There is no recognizable inner wall, except occasionally near the branchlet terminals. The plane of the aperture, *i. e.*, the lip, is nearly at right angles to the surface of the branchlet, but there may be incisions to a slightly lower level against the branchlet. The corallites are labellate, verging toward dimidiate. The outlines of the apertures are elliptical or subcircular. Septa, the 6 primaries distinct, directives larger than the others; secondaries rudimentary, obscure, or absent.

Cœnenchyma reticular, porous, echinulate.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones makes the following notes:

"Fragments of a colony found on the barrier flats north of Pulu Bras, where such colonies are abundant. They are in pools skirted by *Millepora*, on the lagoon margin of the flats. The branches, while alive, are creamy white; their distal ends and terminal polyps pink."

This specimen has greatly puzzled me, as it does not precisely accord with typical specimens of any of the species with which I have compared it, but it is too similar to *A. spicifera* to warrant reference to a different species. It is probably closest to Dana's variety *abbreviata*, which has "branchlets 6 to 25 mm. long, obtuse at the apex, with scarcely prominent axial corallites." A specimen in the U. S. National Museum, No. 234, from Singapore, U. S. Exploring Expedition, now bears the label "*Madrepora spicifera* Dana?" but was originally labeled "*Madrepora microclados* Ehr.?" by Dana.[2] This specimen is undoubtedly the same as the one from Cocos-Keeling Islands, and I am convinced it is *Acropora spicifera*. The diameter of its axial corallites is from 1.5 to 2 mm., averaging less than in the Cocos-Keeling specimen, and the edges of the corallite lips are not always reflected quite so much as in the latter, but there is a distinct tendency toward flaring and there is some flattening of the edge.

Distribution.—Indian Ocean from Gulf of Aden to Ceylon, Singapore, and Keeling Islands; Great Barrier Reef; Fiji Islands; Tongatabu. The range is therefore from the east coast of Africa to Tongatabu.

Acropora (Lepidocyathus) squamosa (Brook).

Plate 72, figures 1, 2, 2*a*, 3, specimen from Murray Island.

1893. *Madrepora squamosa* Brook, Cat. Genus Madrepora, p. 120, plate 20, fig. B.

A description of a specimen of *Acropora squamosa* from Murray Island is as follows:

Corallum corymbose, rising above an expanding base. Height about 17 cm.; greater horizontal diameter about 18 cm.; lesser horizontal diameter about 14 cm. Maximum length

[1]From manuscript notes of Dr. Wood Jones.

[2]Compare Brook's remarks on *Madrepora microclados* (Ehr.), Cat. Genus Madrepora, pp. 102, 103.

of branches about 9 cm.; basal diameter of branches up to 14 mm. or somewhat more. Branches on lower and outer edge of colony shorter and thinner, 3.5 cm. long and 9 mm. in diameter at the base; other branches still smaller. The main branches often subdivide into from 3 to 4 branches near the base; these branches again subdivide into 2 to 4 branches 1.5 to 2 cm. higher up, and smaller lateral branchlets originate still higher. Such branchlets range in size from proliferous corallite up to 4 cm. long, with a basal diameter of 8 mm. The branchlets are more numerous on the outside of the outer branches than on those situated more interiorly. Very little or no anastomosis of branches or branchlets. Distance between terminals 1.5 to 2 cm.

Axial corallites 3 to 3.5 mm. in diameter; exsert, 1.5 mm.; calicular aperture, 1.25 mm. in diameter; walls, 1 mm. thick, texture lax, porous, reticulate, costulate, with synapticulæ between the costules; septa in 2 distinct cycles, the primaries nearly meeting deep down in the calices, the secondaries about one-third the length of the calicular radius.

Radial corallites immersed on the basal expansion and on the lower portion of the branches; higher up there are some proliferous corallites which merge into branchlets. The usual corallites are crowded, spreading, scale-like, only the lower wall developed, rise in close ascending spirals, the lower walls of the next higher spiral rising from the level of the upper margin of the corallites of the next lower spiral, without any immersed corallites between them. Diameter ranges from 2 to 2.75 mm.; length of lip 2 to 2.75 mm. The lower surface of the wall is perpendicular to the axis of the branchlet, while the margin of the aperture may slope slightly downward; farther down on the branch the lower wall ascends and the plane of the aperture is at right angles to the branch axis. Viewed in plan, the outer margin of the wall is rounded, but frequently it is more or less truncate, with rounding at the ends of the truncation. Viewed in profile, the outer edge is usually thin, delicate, and friable, but within there may be appreciable thickening. Lower down on the branches the wall may have a rounded edge. The texture is reticular and on the outside there are delicately granulate costules. Apertural outline circular. Two cycles of septa can usually be distinguished, but only the directives are fairly conspicuous, the outer the more prominent, the others small or rudimentary. In the immersed corallites the septa are more conspicuous.

The cœnenchyma becomes fairly compact; originally it is granulate and flaky.

Stations, Murray Island.—Southeast reef, line I:

1,020 feet from shore; water 16 inches deep at lowest tide; hard, rocky bottom, in a protected place free from current (the specimen on which the foregoing description is based, plate 72, figs. 1, 2, 2*a*, 3).
1,400 feet from shore; depth, 14 inches; bottom hard, rocky. (A colony nearly the size of the one described, some anastomosis of branches.)
1,600 feet from shore; depth, 10 inches; bottom hard, rocky. (One small colony.)

It is my belief that *A. squamosa* (Brook) is the quiet-water facies of the same species of which *A. sarmentosa* (Brook) is the rough-water facies. Additional remarks will be made under the latter.

Distribution.—Great Barrier Reef; Australia.

Acropora (Lepidocyathus) sarmentosa (Brook).

Plate 72, figures 4, 4*a*; plate 73, figure 1, specimen from Murray Island.

1893. *Acropora sarmentosa* Brook, Cat. Genus Madrepora, p. 127, plate 22.

I am attaching this name to two fragments collected by Dr. Mayer. At first I labeled one of them *A. squamosa* and the other *A. sarmentosa*, but they are probably parts of the same colony. I have already stated it is my belief that the latter is the rough-water facies and the former the quiet-water facies of the same species.

Station, Murray Island.—Southeast reef, line I, 1,600 feet from shore; water 10 inches deep at low spring tides.

Acropora (Lepidocyathus) hebes (Dana).

Plate 73, figures 2, 2*a*, Dana's type of *Madrepora hebes*; plate 74, figures 1, 2, 2*a*, 2*b*, specimens from Murray Island. Also plate 13, figure 6, of Dr. Mayer's article.

1846. *Madrepora hebes* Dana, U. S. Expl. Exped., Zooph., p. 468, plate 35, fig. 5.
1893. *Madrepora hebes* Brook, Cat. Genus Madrepora, p. 128.

Dana's type of this species, from Fiji Islands, is in the U. S. National Museum, No. 287, and there is a second specimen, also collected by the U. S. Exploring Expedition, No. 286. The former is represented by plate 73, figures 2, 2*a*. Both Dana and Brook fail to mention the presence of immersed or subimmersed corallites between the labellate corallites. In the larger radial corallites 2 cycles of septa may be complete, but usually the number of secondaries is variable; the upper directive is the most prominent septum.

The following is a description of a specimen collected on line I, 800 feet from shore, Murray Island:

Corallum loosely ramose, with elongate, slowly tapering branches. Branch 91 mm. long has a basal diameter of 11.5 mm.; diameter of terminal corallite, 3.5 mm., the usual diameter of terminal corallites.

Terminal corallites with thick, porous, longitudinally costulate walls; project up to 2 mm.; 2 well-developed cycles of septa, the primaries almost or actually meeting deep down in the center of the calice, a directive septum sometimes conspicuous. Secondaries extending about half the distance from the wall to the center.

Radial corallites crowded, of two kinds, labellate and immersed. The labellate corallites about 2.5 mm. in diameter, measured from the outer edges of the wall; wall well developed only on the lower semi-circumference of the calice, protuberant about 1.5 mm. at right angles to the intercorallite surface, less prominent near the proximal ends of the branches, often thickened within the calice, but the edge is usually thin, texture porous, outside finely costulate; septa, one complete cycle, directives, especially the upper, conspicuous, rudimentary secondaries variable in number. The immersed corallites smaller, 1 mm. or less in diameter, septa less conspicuous. The two kinds of corallites grade into each other.

Cœnenchyma reticular, rather porous, with minute echinulations.

Two specimens from Murray Island are figured (plate 74, figs. 1, 2), in order to show the variation in relative attenuations of the branches and relative frequency of branching. An enlarged view shows the calicular characters. The calices of the Murray Island specimens average larger than those of Dana's type and the wall on the lower side of the calices is more thickened, but the differences seem to me to be due to *vegetative* variation.

Stations, Murray Island.—Southeast reef, line I:

600 feet from shore; depth, 15 inches; bottom sandy; 3 branches.
800 feet from shore; depth, 11 inches; bottom hard, rocky; 2 specimens.
1,200 feet from shore; depth, 9 inches; bottom rocky; 3 specimens.
1,400 feet from shore; depth, 14 inches; bottom hard, rocky; 2 specimens.

Distribution.—Fiji Islands (Dana's types); Great Barrier Reef.

Acropora (Tylopora) digitifera (Dana).

Plate 76, figures 1, 1*a*, 2, specimens from Murray Island. Also plate 13, figure 7, of Dr. Mayer's article.

1846. *Madrepora digitifera* Dana, U. S. Expl. Exped., Zooph., p. 454.
1893. *Madrepora digitifera* Brook, Cat. Genus Madrepora, p. 75.
1902. *Acropora digitifera* Verrill, Trans. Conn. Acad. Sci., vol. 11, p. 228, plate 36, fig. 12; plate 36 B, fig. 3.

The following is the description of a specimen from Murray Island:

Corallum with an incrusting base 92 by 100 mm. in diameter, above which a number of branches rise separately; height of colony about 134 mm.; greater horizontal diameter about 207 mm.; lesser horizontal diameter about half as much. The branch terminals reach nearly to a plane. Basal diameter of a branch, about 13 mm.; branches subdivide about 17 mm. above the basal expansion into two or three subordinate branches about 10 mm. in diameter at the base and 50 to 60 mm. long. Some proliferous corallites grading into branchlets higher up. Branching more diffuse around the periphery of the colony than near the center.

Axial corallites, diameter 3 mm.; exsert, up to 2.5 mm.; septa well developed, primaries almost meeting deep down in the calice, secondaries about half as long as the primaries; wall porous, reticular, and costulate on the outside, but it becomes considerably compacted by secondary deposit.

Radial corallites, usually very unequal in size, of three kinds: (*a*) proliferous, (*b*) non-proliferous protuberant, and (*c*) immersed or subimmersed. (*a*) The proliferous corallites range up to 8 mm, tall (measured along the lower side) and are 3.5 mm. in diameter; the wall is thick, about 1.25 mm., its inner edge is somewhat excavated, its outer edge rounded in profile, secondarily compacted, but externally costulate, 2 cycles of septa, a false columella present. Corallites of this kind grade into branchlets, which are up to 16 mm. long and 5 mm. in diameter at the base. Small, short, labellate, radial corallites occur on the proliferous corallites and the branchlets. (*b*) The non-proliferous protuberant corallites crowded, labellate, spreading at right angles to the branch, smaller near the branch terminal, larger and more prominent lower down, but still lower near the branch bases, mostly immersed with some large; labellate corallites scattered among them, wider at margin than at base. Near terminals, diameter 1.75 mm., project about 2 mm.; lower down, diameter up to 2.5 mm., project up to 2.5 mm. Upper wall poorly developed or absent; lower wall thick, compact, costulate on outer surface, frequently somewhat flattened above. Outer edge more or less rounded in profile. Apertures subcircular in cross-section perpendicular to corallite axis. Lower directive septum prominent; other septa variable in development, usually in two cycles but small in size, rudimentary; however, a false colummella is sometimes present deep within the calice. (*c*) Immersed or subimmersed corallites scattered irregularly between the protuberant ones near the branch terminals; more abundant nearer the base, where they often have 2 well-developed cycles of septa; diameter often only 0.5 mm.

Cœnenchyma costulate, echinulate, decidedly compact.

Stations, Murray Island.—Southeast reef, line I:

1,400 feet from shore; depth, 14 inches; bottom hard, rocky.
1,600 feet from shore; depth, 10 inches; bottom hard, rocky.

Distribution.—Great Barrier Reef; Madagascar (Brook). The locality of the type is unknown (see Verrill, *op. sup. cit.*).

Professor Verrill has rendered a valuable service in publishing figures of a branchlet from Dana's type. The Australian specimens completely agree with his figures, except that the axial corallites are often, but not always, more exsert. The range of variation of this feature in Dana's type has not been published.

Acropora (Tylopora) scherzeriana (Brüggemann).

Plate 75, figures 1, 2, 2*a*, 2*b*, 3, 3*a*, 4, specimens from Cocos-Keeling Islands.

1906. *Acropra scherzeriana* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien., vol. 80, p. 41, plate 12, figs. 27–31; plate 13, figs. 27*a*, 29*a*, 31*a*, 32–35; plate 18, fig. 28*a* (with synonymy).

Although von Marenzeller has elaborately described this species and reference may be made to his work, I am publishing figures to show its characters and variation at Cocos-Keeling. Besides these specimens, there is in the U. S. National Museum a complete corallum, obtained by Dr. W. L. Abbott in the western Indian Ocean, probably at Aldabra. In 1906[1] I referred to a species from Mangareva as *Acropora* aff. *A. canaliculata* (Klunzinger). A restudy of the species leaves me still in doubt, as the calices are not laterally compressed, as is usual on branches of similar form in *A. scherzeriana.*

Habitat, etc., Cocos-Keeling Islands.—"A common barrier species. While living it is yellow; the zooids are pale," according to Dr. Wood Jones. The species is represented by 6 fragments, apparently from 3 colonies.

[1]Bull. Mus. Comp. Zool., vol. 50, p. 70, plate 5, figures 1, 1*a*, 1*b*.

Distribution.—Red Sea; Indian Ocean. Closely related species widely distributed in the Pacific, but *A. scherzeriana* has not yet been positively identified in that region.

Acropora (Tylopora) gemmifera (Brook).

Plate 77, figures 1, 1*a*, 2, 2*a*, 3, 3*a*, specimens from Murray Island.

1893. *Madrepora gemmifera* Brook, Cat. Genus Madrepora, p. 142, plate 31.

Dr. Mayer obtained a fair suite of specimens of this species, which shows a wide range of variation. A selected series is illustrated and the following annotations are made on the specimens according to their habitat:

Plate 77, figures 1, 1*a*, are views of a specimen from 6 miles east by north of Murray Island, inner side of the reef patch, water 3 to 4 feet deep, coral-rock bottom. This was a healthy colony. It is especially characterized by the prominent, compressed, nariform, gutter-shaped, or dimidiate radial corallites of the upper surface. Because of the pronounced compression of the radial corallites, I at first doubted its being *A. gemmifera*, but careful comparison with the specimen next to be considered convinced me that they are variants of the same species.

Plate 77, figures 2, 2*a*, represent a specimen from the same locality. It is very similar to Brook's type. Radial corallites are less prominent and less compressed than in the first-mentioned specimen, but the two intergrade. This variant is represented by a second specimen from the same station.

Plate 77, figures 3, 3*a*, illustrate a specimen from the inner edge of one of the outer reef patches of the Great Barrier Reef, 6 miles east of Murray Island, water about 4 feet deep, in a strong current and subject to breakers. The base is overgrown by Lithothamnion, which extends up many branches. The branches are reduced in diameter, and the radial corallites project very slightly or not at all, except in one protected place on the periphery.

Two stunted specimens, one dead, the other nearly dead, were collected on the Lithothamnion ridge of Murray Island.

Distribution.—Great Barrier Reef, Australia.

The species is very closely related to *A. scherzeriana*. The most important differences are the smaller axial corallites, the more persistent presence of small, scale-like corallites on the larger radial corallites, and a larger number of more prominent proliferous radial corallites in *A. gemmifera*. Brook has given a good description, which needs to be supplemented by the foregoing notes under the first and third variant.

Acropora (Tylopora) ocellata (Klunzinger) var.

Plate 76, figures 3, 3*a*, 3*b*, specimen from Cocos-Keeling Islands.

1879. *Madrepora ocellata* Klunzinger, Korall. Roth. Meer., pt. 2, p. 9, plate 1, fig. 7; plate 4, fig. 14; plate 9, fig. 5.
1893. *Madrepora ocellata* Brook, Cat. Genus Madrepora, p. 148.
1906. *Acropora ocellata* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 26, plate 18, fig. 81*a*; plate 24, fig. 81.
1907. *Madrepora pulchra* Wood Jones, Proc. Zool. Soc. London for 1907, p. 531, text-fig. 154, plate 27, fig. 2*c*.
1910. *Madrepora pulchra* Wood Jones, Coral and Atolls, p. 89, fig. 24*c*; p. 93, fig. 27.

The specimen here considered represents a rough-water facies which has greatly puzzled me. At first I thought it might be an environmental adaptation of *A. scherzeriana*, but it lacks the mural costulation of that species. The following is Brook's description of *A. ocellata:*

"Corallum low, cespitose, 8 to 10 cm. wide and 2 to 4 cm. high. Branches digitiform, obtuse, little divided excepting near the apex, 2 to 4 cm. long, 1 cm. thick. Axial corallites 4 to 5 mm. broad and 1 to 2 mm. exsert, thick-walled with rounded margin and small

(1 mm.) aperture. Radial corallites not crowded, usually nariform or tubular, 3 to 4 mm. long and 2 mm. broad, slightly compressed; aperture small, round elliptical or oblique, outer part of wall a little thickened and margin rounded; some of the tubular ones are elongate (7 mm.). Near the base of the branches the corallites are verruciform with a few immersed ones interspersed. Corallum porous above; surface echinulate or spongy-reticulate; wall not striate.

"A specimen from Ceylon described by Ortmann differs from the type in having smaller axial corallites, 3 to 4 mm. diameter and 1 mm. exsert. The species approaches *M.* [*Madrepora*] *klunzingeri* closely, and differs chiefly in the form of the radial corallites and in the thickness of the wall.

"Indian Ocean; Red Sea; Ceylon.

"*a*. Ceylon. Haeckel Coll. 92.12.5.7."

The texture of the Cocos-Keeling specimen is decidedly compact, but this is a recognized adaptation to rough water, and the surface is densely granulate, with secondary minute frosting. In plan the granules show arrangement along more or less definite lines. The septa are strikingly well developed, as is usual in stunted specimens of the genus. Two cycles are persistently present, and in some axial corallites a varying number, up to about 8, of rudimentary tertiaries may be detected.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones says: "From the extreme rough water of the barrier. The color is usually yellowish; sometimes brown."

Acropora (Isopora) palifera (Lamarck).

Plate 78, figures 1, 1*a*, 1*b*, 1*c*, 1*d*, Dana's type of *Madrepora labrosa;* plate 79, figure 1, specimen from Cocos-Keeling Islands; figures 2, 3, 4, 4*a*, 4*b*, variety *a* (Brook), from Murray Island. Also plate 13, figure 8, of Dr. Mayer's article.

1893. *Madrepora palifera* Brook, Cat. Genus Madrepora, p. 131 (with synonymy).
1893. *Madrepora hispida* Brook, Cat. Genus Madrepora, p. 133, plate 9, fig. C.
1907. *Isopora hispida* Bedot, Madréporaires d'Amboine, p. 262, plate 42, figs. 235–239.

Dana's type of *Madrepora labrosa* (see plate 78, all figs.), which Brook referred to the synonymy of *Astrea palifera* Lamarck, is preserved in the U. S. National Museum, No. 315. Although both Dana and Brook grasped the important characters of the species, some of the features need elaboration. The corallites near the branch summits range from 2.75 to 3.5 mm. in diameter; lower down the diameter may be only 1.5 mm., while on the base it may be as little as 1 mm. Upper wall less developed than lower, often absent. Septal pairing often obvious. The radial corallites are crowded in places, especially near the branch terminals, or are considerably separated, 0.5 to 0.75 mm. The lower wall especially shows crowded, flattish, spinulose costules. The cœnenchyma is beset with crowded, more or less twisted spinules which may be arranged in rows.

Madrepora hispida Brook seems to me to be a form of *Acropora palifera* with corallites slightly smaller than the average.

Dr. Mayer collected a good suite of specimens of this species around Murray Island (see plate 79, figs. 2, 3, 4, 4*a*, 4*b*). The radial corallites do not attain so large a size as in the type specimen of *A. labrosa*, 2.75 mm. being about the maximum diameter, and a larger proportion of them are subtubular. In most specimens the branches are not so plate-like as in *A. labrosa* (type); but in some they are plate-like. The usual form is Brook's variety *a*, concerning which he says:

"The specimens numbered *k* to *n* come somewhat intermediate between typical *M. palifera* and *M. brueggemanni.* They have thick branches with broad flat apices, or even sometimes there is only one axial corallite. The radial corallites are irregular, and some are somewhat elongate with a convex outer margin such as occurs in *M. brueggemanni* var. *uncinata;* in other cases the wall is rough and there is an approach to *M. hispida.*"

The last clause shows that Brook was aware of the close relation of some of the Great Barrier Reef specimens to his *hispida*. A number of the incipient branchlets of the Murray Island specimens have only a single axial corallite, indicating close relationship to the subgenus *Tylopora*.

The specimens (see plate 79, fig. 1) obtained by Dr. Wood Jones in the Cocos-Keeling Islands differ from the type of *A. labrosa* in having radial corallites which average longer, up to 5 mm. (their length in the type 2 to 3.5 mm.).

Stations, Murray Island.—Line I, southeast reef:

800 feet from shore; depth 11 inches; bottom hard, rocky.
1,000 feet from shore; depth 17 inches; bottom rocky.
1,200 feet from shore; depth 9 inches; bottom rocky.
1,400 feet from shore; depth 14 inches; bottom hard, rocky.
1,600 feet from shore; depth 10 inches; bottom hard, rocky.
Lithothamnion ridge, 1,725 to 1,775 feet from shore (an incrusting lamina).
6 miles east-northeast from Murray Island, inner side of a reef patch of the outer barrier reef, south of Cumberland's Entrance; depth about 4 feet at lowest tide; bottom rocky.

The only specimen which suggests variation in response to habitat is the one from the Lithothamnion ridge.

Habitat and color, Cocos-Keeling Islands.—Dr. F. Wood Jones states:

"From the lagoon at the eastern side of Pulu Tikus, water 1 fathom deep. The colony the only one of its kind found, was luxuriant, made up of large, flat branches over 2 feet in height. Colony pale buff yellow in color; the zooids pale."

Distribution.—The following localities are represented in the U. S. National Museum: Corregidor Light, Manila Bay, *Albatross*, 1908; southern Philippines, J. B. Steere; Sulu Sea (Dana's type of *A. labrosa*). Brook records specimens from New Guinea, Solomon Islands, China Sea (Tizard Bank, 5 fathoms), and Diego Garcia. Bedot reports it, as *A. hispida*, from Amboina.

Acropora (Isopora) plicata (Brook)

Plate 80, figures 1, *1a*, *1b*, from Murray Island.

1893. *Madrepora plicata* Brook, Cat. Genus Madrepora, p. 134, plate 9, fig. D.

Brook's description of this species is excellent and fits two specimens collected by Dr. Mayer at Murray Island. The striking specific characters are the relatively short (2.5 to 8 cm. long) and thick (average about 1 cm.) plate-like branches, along the surfaces of which are longitudinal ridges, bearing rosettes of corallites, composed of a central larger surrounded by smaller corallites; and the tubular radial corallites, which range from 1 to 2 mm. in diameter, are appressed near the branch ends and spreading lower down, the walls are thin, and the apertures relatively large. Two cycles of septa are usually distinct, but small, except the directives, which are wide; four of the primaries are only slightly larger than the secondaries.

This species groups with *A. securis* (Dana), type No. 304, U. S. National Museum, and *A. cuneata* (Dana), type No. 334, U. S. National Museum, as Brook clearly stated. All three have tubular corallites and longitudinal ridges, with rosettes of corallites, on the sides of the plates. The corallites in both *A. securis* and *A. cuneata* are more spreading than in *A. plicata*.

A. securis has corallites of nearly the same diameter as *A. plicata*, but they average decidedly more prominent, a height of 3 mm. being common. In addition to the differential characters mentioned, the plates of *A. securis* are taller, thinner, and more squarely truncate on top than are those of *A. plicata*.

In *A. cuneata* the radial corallites near the plate summits have about the same diameter (about 2 mm.) as in *A. plicata*, but lower down on the sides of the

plates the diameter is usually less, between slightly less than 1 mm. and 1.5 mm., and the corallites are crowded. The usual diameter of well-developed radial corallites in *A. plicata* is nearly 2 mm., but the diameter of some corallites is only 1 mm. The shapes of the plates are very similar in both, but as *A. cuneata* has more spreading, more crowded, and smaller radial corallites than *A. plicata*, it has a decidedly different appearance.

These are three closely related species, and possibly larger collections may result in combining *A. plicata* with *A. cuneata*, but, according to the material at present before me, all are distinct.

Stations, Murray Island.—Southeast reef, line I:

1,400 feet from shore; depth 14 inches; bottom hard, rocky.
1,600 feet from shore; depth 10 inches; bottom hard, rocky.

Distribution.—Tongatabu (Brook, type); Rocky Island, Great Barrier Reef (Brook); Murray Island, Torres Strait.

Acropora (Conocyathus) polymorpha (Brook).

Plate 81, figures 1, 2, 3, 4, 5, specimens from Fanning Island.

1846. *Madrepora abrotanoides* Dana, U. S. Expl. Exped., Zooph., p. 477, plate 41, fig. 1 (*non* Lamarck).
1893. *Madrepora polymorphra* Brook, Cat. Genus Madrepora, p. 169, plate 31, figs. B to D.

A fine suite of this species was collected at Fanning Island by Dr. Fred Baker and Mr. C. Elschner. Brook's description is excellent and is quoted in full.

"Corallum fruticose, spreading ramose; branches 8 to 20 cm. long, usually about 1.5 to 2 cm. thick, gradually tapering; the branches bear numerous branchlets, spreading usually at an angle of 80° to 90°, and varying in importance from thickened and elongate proliferous corallites to subterete and tapering twigs 4 cm. long and 1 cm. thick. Axial corallites 1.5 to 2 mm. diameter and 0.5 to 2 mm. exsert, wall thick or comparatively thin. Radial corallites compressed nariform or tubo-nariform, unequal, the longer ones becoming tubular and proliferous. Some distance below the apex all become verruciform with a dilated wall, which gradually becomes reduced to a ring-shaped fold. Immersed corallites are usually wanting even in the older parts of the colony, but in one or two specimens, which agree closely in other respects, immersed corallites may take the place of those with a ring-shaped lip. Radial corallites 1.5 mm. diameter or under, and 1.5 to 3 mm. or more in length; aperture oval, wall varying in thickness in different specimens; always thickened some distance below the apex of a branch, and in some cases quite to the apex; in the latter case the wall of the axial corallites is also thickened. The axial corallites are provided with 12 septa, none of which are very prominent; those of the radial corallites are also usually narrow, including the directives; in the corallites situated some distance from the apex the second cycle is almost as well developed as the first. Corallum dense, even near the apex of a branch in most specimens; surface and wall finely and closely echinulate.

"The species which Dana referred to *M. abrotanoides* is quite distinct from the type of Lamarck, with which the description given by M. Edwards agrees closely. The description and figure of Dana agree very well with the species here described and I have therefore placed the name as a synonym. It is possible that more recent authors may have taken Dana's species for the true *M. abrotanoides*, and the synonymy is thus uncertain at present.

"There is considerable variation in this species, both in the branching and in the thickness of the corallite-wall. The specimens which have come under my notice fall more or less completely into three groups:

"*a.* Branches elongate; corallite-wall thin or only slightly thickened near the apex of a branch, but becoming considerably thickened below. A few immersed corallites may or may not occur near the base of the branches.

"*b.* Branches shorter and more subdivided; corallites often 2.5 mm. diameter, all with thick wall and rounded lip. No immersed corallites.

"*c.* Branches thick and stunted, with short branchlets. Immersed corallites extending between the bases of the branchlets to near the apex.

"Indo-Pacific Ocean; Malacca; ?Fiji."

As Brook's figures are not satisfactory, I am publishing five figures, which show the range of variation exhibited by the suite of Fanning Island specimens. Brook has correctly identified the specimen referred by Dana to "*Madrepora abrotanoides*."

Distribution.—Malacca; Fiji Islands; Fanning Island. This evidently is a widely distributed species.

Acropora (Rhabdocyathus) variabilis (Klunzinger).

Plate 80, figures 2, 3, 3*a*, 3*b*, specimen from Cocos-Keeling Islands.

1879. *Madrepora variabilis* Klunzinger, Korall. Roth. Meer., pt. 2, p. 17, plate 1, fig. 10; plate 2, figs. 1, 5; plate 5, figs. 1*a*, 1*b*; plate 9, fig. 14.

1906. *Acropora variabilis* von Marenzeller, Denksch. k. k. Akad. Wissensch. Wien, vol. 80, p. 23, plate 15, figs. 40–44.

Each of two sets of fragments representing two colonies, obtained by Dr. Wood Jones in Cocos-Keeling Islands, will be described separately:

Specimen No. 1 (plate 80, fig. 2):

Corallum represented by four fragments, which have the following dimensions:

Dimensions of branches of Acropora variabilis.

Branch No.	Length.	Basal diameter.	Axial corallite.	
			Diameter.[1]	Exsert.
	mm.	*mm.*	*mm.*	*mm.*
1	46.5	9 × 10	3	2
2	45.5	6.5	3.5	2
3	63	9	3	2
4	80	about 11.5	3	

[1]Measured at the base of the corallites.

The growth-form, which must be inferred, was apparently cespitose. The main branches subdivide as shown in the figures and there are elongate proliferous corallites or short twigs, ranging in length from 7 to 16 mm., and in basal diameter according to length from 2.5 to 5 mm.; diameter of axial corallites of such twigs about the same as that of the axial corallites of the larger branches. Abnormal axial corallites on twigs near the base of one branch range in diameter from 4 mm. to 4.5 by 6 mm. Axial corallites of the larger branches slightly taper from the base to the aperture. The diameter at the base is given in the table; that at the aperture is about 2.5 mm., or it may be slightly less. The walls are thick, reticulate, become secondarily compact, outer surface granulate, sometimes obscurely but not obviously costulate. Apertures small, from 0.5 to 0.75 mm. in diameter. The primary and usually the secondary septa are distinct, all of which are occasionally subequal.

The radial corallites are very unequal in size; just below the axial corallites they are small, diameter 1.5 mm., length 2.5 mm., or even smaller, and are appressed tubiform with the outer wall much thicker than the inner. Lower down, within about 8 mm. from the branch tip, the corallites are much larger and attain their normal full size. The proliferous corallites have already been mentioned; besides these there are ascending, more or less twisted, tubiform corallites up to 5.5 mm. long and 2.25 by 2.5 mm. in diameter, and appressed tubiform corallites, 4 mm. long and 1.75 mm. in diameter, irregularly scattered between the bases of which are subimmersed corallites which may be only 0.75 mm. in diameter. All kinds of radial corallites intergrade; the tubular grade into the proliferous, and the latter become axial corallites. Low down on the branches some radial corallites are appressed veruciform. The walls are thick, early become compact, outer surface closely granulate without definite costules. Apertures small, about 0.75 mm. in diameter, subelliptical, usually more or less eccentric, nearer the inner than the outer margin of the corallite, and often inclined, as the outer wall usually extends somewhat beyond the inner. Frequently the outer wall is somewhat tumid just below the aperture and curves up to it. Except in very young corallites

the primary septa are well developed, but do not reach the center, the directives may be somewhat more prominent than the others of the cycle; the secondaries much smaller, but usually distinct.

Cœnenchyma compact, surface closely granulate, without definite costules.

Specimen No. 2 (plate 80, figs. 3, 3a, 3b):

Corallum cespitose, corymbose, rising from an incrusting base. Height of colony about 14 cm., horizontal diameter about 25 cm. There is some distal anastomosis of the branchlets. The dimensions of branches and branchlets of this specimen are as follows:

Measurements of branches and branchlets of Acropora variabilis.

Branches.				
Branch No.	Length.	Basal diameter.	Axial corallites. Diameter.	Axial corallites. Exsert.
	mm.	*mm.*	*mm.*	*mm.*
1	47	6	2.5	1
2	70	6.25×7	2.5	1.25

Branchlets.				
Branchlet No.	Length.	Basal. diameter.	Axial corallites. Diameter.	Axial corallites. Exsert.
	mm.	*mm.*	*mm.*	*mm.*
1	10	3.5	2	1.25
2	24	4	2.5	1.5
3	25	3.25	2.25	1.5
4	32.5	4×5	2.5	1.5
5	21	4	2.5	1.5
6	34	4.25	2.5	1.5

Axial corallites, dimensions and exsertness as stated in the table; subcylindrical in form, summit flattish, with the upper edges of the walls slightly rounded, except on some abnormal branches near the base in which there is slight tapering with constriction toward the aperture. Walls reticular; texture loose in young, dense in old corallites; thickness about the same as or slightly greater than the diameter of the aperture; outer surface granulate, indistinctly costulate. Aperture broadly elliptical; diameter about or slightly less than one-third that of the corallite. Septa, primaries well developed, subequal, or the directives somewhat more prominent; smaller secondaries usually obvious.

Radial corallites relatively uniform in size; appressed tubiform or ascending tubiform; frequently arranged in somewhat irregular rows. Usual size 3.5 mm. long, 1.5 mm. in diameter, with the calice of one corallite at the base of the one next higher. Tubiform corallites may be 4.5 or 5 mm. long and 2 mm. in diameter. A few subimmersed or small appressed tubular corallites are scattered between the bases of the larger corallites. Toward the base of the branches most corallites become immersed or appressed nariform; over considerable areas at the branch bases there may be no calicular apertures. In the appressed corallites the outer wall is thicker than the inner and rises slightly higher, thus causing the aperture to be inclined; often it curves just below its upper edge so as to be nearly parallel to the branch axis; its texture is reticular, becoming compact in old corallites; its outer surface granulate, and in places obscurely costulate. In free tubular corallites the inner wall may almost equal the outer in thickness. The apertures are elliptical or oval in outline, nariform in the appressed and elliptical in the free tubular corallites; the diameter approximately one-third that of the corallite. The directive septa distinct, the other primaries usually recognizable but smaller; very small rudimentary secondaries can usually be distingui·hed.

Cœnenchyma finely echinulate, flaky; becomes dense.

A comparison of the descriptions of No. 1 and No. 2 shows that they are similar as follows: (1) growth-form and general facies; (2) in the structural characters

of the corallum; (3) the form of the radial corallites; (4) the septal characters are according to the same plan. The differences are as follows: (1) the branches of No. 2 are more slender; (2) the axial corallites smaller and less exsert; (3) the radial corallites are smaller and more uniform in size; (4) the walls of the radial corallites are less dense and somewhat rougher. Without large suites of complete coralla on which variation may be studied, it is not possible to evaluate the differences. The appearance is that the two sets of fragments represent variants of one species.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones says regarding the species:

"Flourishes upon the barrier flats and is able to withstand a considerable degree of rough water. It is easily killed in sedimentary pools. The colonies form dense branching tufts, and have a very characteristic purple coloration of the terminal zooids."

Distribution.—Red Sea; Indian Ocean; Great Barrier Reef; Tongatabu; Samoa.

Acropora (Rhabdocyathus) murrayensis, new species.

Plate 82, figures 1, 1*a*, 1*b*, specimen from Murray Island. Also plate 12, figure 5, of Dr. Mayer's article.

The following is a description of the type specimen of this species:

Corallum of subconical growth-form; that is, there is a central stem from which branches radiate outward on all sides and attain nearly the same length at any level, but the length decreases uniformly from summit to base. Height of specimen, 131 mm.; 97 mm. below summit, diameter 60 by 76 mm.; 13 mm. below summit, diameter about 30 mm. Branch near base, maximum length 47.5 mm.; diameter of proximal end, 8 mm.; axial corallite, diameter 3.25 mm.; exsert 1.5 mm. Short branch near apex, length 12 mm.; diameter of base, 5 mm.; axial corallites, diameter 3.4 mm., exsert 1.4 mm. Branches simple or give off from 1 to 9 branchlets; some of the larger branchlets have secondary branchlets. Distance between axial corallites of a series of branches in a vertical plane, from 12.5 to 17.5 mm.; in a horizontal plane, from 8 to 21 mm.

Axial corallite of main stem, diameter 3.75 mm.; exsert slightly less than 1 mm. Walls thick; outer edge rounded; texture closely reticular, with interspaces of less area than the solid structures. Primary septa well developed, equal, not meeting in the axis; secondary septa distinct but small. The axial corallites of the branches and branchlets similar to the axial corallite of the main stem but slightly less in diameter and slightly more exsert, and in some the directive septa are more prominent than the other primaries.

The radial corallites are prominent to within between 5 and 6 mm. from the branch tips. No immersed corallites except near base of main stem. The protuberant corallites occur in fairly definite spirals and are of two kinds, proliferous and non-proliferous. The former are tubular, but with a somewhat better developed outer than inner wall; diameter very nearly 3 mm., length from 3.5 mm. to that of short branchlets, 12 mm. or more. The other radial corallites are short appressed tubular; the outer wall makes an angle of about 45° with the branch surface; plane of aperture about perpendicular to the branch surface. Length 2.5 to 3.5 mm., diameter 2.5 to 2.75 mm. The outer wall is thick and except very near the branch ends is rounded; outer surface closely granulate. The inner wall is fused to the branch surface. Apertures broadly elliptical, more or less labellate. Primary septa distinct, the directives the more prominent; secondaries small, but usually recognizable. Low down on the branches the corallites become less prominent; on the base of the main branch they are mostly subimmersed; the septa in the calices of such corallites are conspicuously well developed in two cycles.

Cœnenchyma closely granulate, becoming dense; no perceptible costules.

Stations, Murray Island.—Southeast reef, line I:

1,600 feet from shore; depth, 10 inches; bottom hard, rocky.
1,630 feet from shore; depth, 16 inches; bottom hard, rocky.

Distribution.—Murray Island.

It seems to me that Brook placed this species under *A. rosaria* (Dana) for he says of the latter, "Corallum very dense, surface and wall closely and finely echinu-

late."[1] Until I had closely studied the specimen just described and had compared it with the type of *A. rosaria*, I thought they belonged to the same species, but *A. murrayensis* has a much denser texture and it has not the costules so conspicuous on both the axial and radial corallites in *A. rosaria*. *A. murrayensis* is very close to *A. squarrosa* (Ehr.), of which it may be only a growth-form.

Acropora (Rhabdocyathus) squarrosa (Ehrenberg).

Plate 83, figures 2, *2a*, *2b*, specimen from Murray Island.

1906. *Acropora squarrosa* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 46, plate 14, figs. 36–39 (all figures).

Description of specimen from Murray Island:

Corallum cespitose, rising as a number of separate branches from an incrusting base. Height about 12.5 cm. Branches about 60 mm. long; basal diameter about 10 mm. There are irregularly distributed lateral branchlets and proliferous corallites, but some branches show subequal branchlets at the same level. A branchlet 22 mm. long may have a basal diameter of only 3.5 mm.

Axial corallites, 2.5 to 3 mm. in diameter, exsert 1 to 2.5 mm.; walls thick, reticulate, become compact, externally granulate, with perceptible costules; aperture about 1 mm. in diameter; septa in 2 distinct cycles, the directives somewhat the longer, the secondaries shorter than the primaries.

Radial corallites, mostly appressed tubiform, or tubiform and proliferous near the branch terminals; near the branch bases they are mostly immersed. The proliferous corallites range in size from a length of 4 mm. and a diameter of 2.25 mm. to well-developed branchlets. The usual protuberant corallites are about 3 mm. long and 2 mm. in diameter. The outer wall rises at an angle of about 45°; plane of the aperture nearly perpendicular to surface of branch. Outer wall thicker than the inner, becomes dense, upper edge slightly rounded; surface echinulate, with some indefinite costulations. Inner wall ranges in condition from that of fusion to side of the branch to that found in tubular corallites. Apertures broadly elliptical or oval, labellate or subnariform.

Primary septa distinct, the upper directive often the more prominent; secondaries often well developed but small. Frequently the septa show the following arrangement: the upper (dorsal) and lower (ventral) directives mark the plane of symmetry; both of these are free from lateral septa, but the two primary and the two secondary septa distal of the upper (dorsal) directive on each side of the plane of symmetry may form four pairs, while the secondaries, one on each side, next the ventral directive remain free. The septal grouping is similar to that of those species of *Porites* in which the inner ends of the members of the triplet are all free, but with two lateral pairs on each side of the plane of symmetry.

Cœnenchyma firmly but roughly echinulate, decidedly dense.

Station, Murray Island:—Southeast reef, line I, 1,400 feet from shore; depth 14 inches; bottom hard, rocky.

This differs from *A. murrayensis* by its growth-form and its smaller corallites. The presence of distinct lateral pairs of septa is noteworthy as indicating relationship with the Poritidæ. *A. glauca* (Brook) is very close to, if not a synonym of, this species.

Distribution.—Red Sea; Australia.

Acropora (Rhabdocyathus) rosaria (Dana).

Plate 82, figures 2, *2a*, *2b*, Dana's type of the species.

1846. *Madrepora rosaria* Dana, U. S. Expl. Exped., Zooph., p. 465, plate 36, fig. 3.

Notes on the texture and ornamentation of the corallite walls of this species are given in the remarks following the description of *A. murrayensis*. The figures (plate 82, figs. 2, *2a*, *2b*) are intended to show the growth-form, the septal and

[1] Cat. Genus Madrepora, p. 179.

other calicular characters, and the surface ornamentation of the corallite walls and of the cœnenchymal surface. I believe Brook misidentified the species.

Type: No. 281, U. S. National Museum.

Locality.—Fiji Islands.

Acropora (Rhabdocyathus) syringodes (Brook).

Plate 83, figures 1, 1*a*, 1*b*, 1*c*, 1*d*, specimen from Murray Island.

1893. *Madrepora syringodes* Brook, Cat. Genus Madrepora, p. 177, plate 33, fig. E.

A description of a specimen from Murray Island is as follows:

Corallum with an incrusting base, from which branches extend subhorizontally to beyond 28 cm., diameter across direction of elongation 20 cm. There is considerable anastomosis both near the base and among the peripheral branches and branchlets, but without plate formation. Basal diameter of largest branch, 22 mm. Branches, branchlets, and twigs relatively slender. Although the specimen is unfortunately badly broken, the following table will give an idea of the attenuation of the branch terminals:

Measurements of branches and twigs of Acropora syringodes.

Branches.			
Branch No.	Length.	Diameter proximal end.	Diameter distal end.
	mm.	*mm.*	*mm.*
1	96	7.5	4.0
2	95	8.0	3.5
3	104	8.0	3.5

Twigs.				
Twig No.	Length.	Basal diameter.	Axial corallites.	
			Diameter.	Exsert.
	mm.	*mm.*	*mm.*	*mm.*
1	39	4.5	2.5	1.5
2	23	3.0	2.3	2.0
3	9.5	2.5	2.0	2.0
4	7	2.0	2.0	2.0
5	30	3.75	2.3	1.5
6	11	2.25	2.25	2.6
7	8	2.40	2.40	2.0

Axial corallites, dimensions as given in the tables; margins not definitely rounded. Walls, thickness about one-third the corallite diameter; texture reticulate, only moderately dense; outer surface with distinct costules, synapticulæ in the intercostular spaces. Septa, first cycle well developed, meeting or nearly meeting in the axis; secondaries variable in development, the cycle incomplete or complete, where complete lateral pairing may be well developed.

Radial corallites on distal part of branches and branchlets ascending tubo-nariform, appressed tubo-nariform, or appressed tubular; outer margin sometimes rounded; length, 3 to 3.5 mm.; diameter, about 1.5 mm.; distance between corallites at the distal ends about 2 mm. Costules distinct and finely echinulate on some corallites; on others the outer surface is finely echinulate without obvious costules. The walls tend toward compactness, and often are solid and of vitreous appearance. Apertures elliptical. Primary septa well developed, directives broad, meeting or nearly meeting each other; secondaries variable in development, the cycle complete or incomplete, uniformly present in the interseptal loculi next the outer directive. Some of the radial corallites resemble the axial corallites; these may become proliferous and develop into branchlets. The walls of the proliferous corallites only a little below the level of the aperture may be dense and subvitreous. Nearer the base of the branches the corallites are less prominent; on the upper surface they are

crowded, appressed tubular or tubo-nariform, with occasional immersed corallites between; on the lower surface there are many immersed corallites, and near the base there may be no calicular apertures.

Cœnenchyma echinulate-costulate; becomes very dense and subvitreous.

Station.—Off northwest reef, Murray Island; depth 15 fathoms.

Distribution.—Great Barrier (figured type from Palm Island); Samoa; South Seas (Brook).

Acropora syringodes groups with *Acropora carduus* (Dana), with which Brook also associates *A. striata* (Verrill). The specimen just described does not completely accord with the description of *A. syringodes*, but the form of the branchlets and the size and arrangement of the corallites are so similar that it can scarcely belong to another species. The looser branching may be attributed to its growth in deeper water.

Family PORITIDÆ Dana.

Genus GONIOPORA Quoy and Gaimard.

1833. *Goniopora* Quoy and Gaimard, Voy. de *l'Astrolabe*, Zool., vol. 4, p. 218.

Type species: *Goniopora pedunculata* Quoy and Gaimard.[1]

Bernard, in his catalog of *Goniopora*, abandoned any attempt to group specimens into species and merely described the morphologic variations of the specimens according to localities. He recognized twelve variations in the Great Barrier Reef, six in northwest Australia, and one variation from Australia without definite locality. *Goniopora fruticosa* Saville-Kent and *Goniopora calycularis* (Lamarck) appear to be the only species based on specimens from Australia. Bernard, in his "Supplementary List of Goniporæ,"[2] adds three variations to the Great Barrier Reef fauna, one to that of Torres Strait, and one to that of Northwest Australia.

Goniopora tenuidens (Quelch).

Plate 84, figures 1, 2, specimens from Murray Island. Also plate 14, figure 17, of Dr. Mayer's article.

1886. *Rhodaræa tenuidens* Quelch, Reef Corals, *Challenger* Reports, p. 188, plate 8, figs. 7, *7a*, *7b*.
1903. *Goniopora Moluccas* (1)1 Bernard, Cat. Goniopora, p. 65, plate 4, fig. 7

As this species is represented by a suite of 14 specimens, the opportunity will be used to describe it in detail. First a healthy specimen of average appearance will be described and the others will be compared with it.

(1) The form is pulvinate. The initial colony grows from a small base into a subspherical corallum attached on one side, with a well-developed basal epitheca. The older part of the corallum dies and successive cushion-like growths form on top. The superposition of cushions may be repeated two or more times, but apparently does not result in the production of tall columns composed of what appear to be successive caps as does one of the Oligocene fossil species from Anguilla, British West Indies. Total height of specimen, 102.5 mm.; greater diameter, 95 mm.; lesser diameter, 65 mm. (including dead corallum), 51 mm. (living part). One other specimen is larger, but none exceeds the size of a man's double fists.

The usual diameter of a fully developed calice is 3 mm.; very young ones may be less than 1 mm. in diameter, while there are a few monsters, one is 5 mm. in diameter. Depth up to 2.5 mm., probably a little more. Although the usual method of asexual reproduction is by gemmation in the angles between the calices, equal fission occasionally takes place.

The walls are usually simple and narrow; in places show some zigzagging; perforate between the septa, which have thickened upper and outer ends; occasionally there is some reticulum where the calices are not so crowded.

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[1]See Bernard's notes on this species, Cat. Goniopora, p. 36, 1903.

[2]Brit. Mus. (Nat. Hist.), Cat. Madreporaria, vol. 6, pp. 145–164, 1906.

There are six prominent septa, considered primary septa, which are thicker than the other septa and extend to the columella. They slope steeply in their upper part, widen below, and bear conspicuous paliform lobes, which do not reach the level of the top of the wall, but stand above and surround a narrow columellar fossa. The secondary septa are smaller than the primaries but are well developed; they fuse to the sides of the primaries near the columella. The tertiaries are small; sometimes they fuse to the sides of a primary, *i. e.*, one of the largest septa, but usually are represented by vertical rows of spines. Septal faces, especially the paliform lobes, coarsely granulate.

Columella present, variable in development, composed of a few rather coarse interfusing trabeculæ connected with the septa. It averages in diameter about or somewhat less than one-third that of a calice.

Specimen on which the preceding description is based obtained from station at Murray Island, southeast reef, line I, about 600 feet from shore; water about 15 inches deep; bottom sandy.

(2) Specimen from station 500 to 550 feet from shore, water about 15 inches deep, sandy bottom: Growth-form pulvinate; greater diameter, 67.5 mm.; lesser, 47.5 mm.; height 39 mm. Average diameter of fully developed calices 2.5 mm.; fossæ, deep. Walls thin, simple, or walls of adjacent calice with cells between costal ends of septa. Primary septa well developed, fusing to columellar tangle, but thinner than in the specimen of the preceding description; paliform thickenings and lobes only indicated, not greatly developed. Although the growth-form and the septal plan in this and the preceding specimen are the same, the secondary and tertiary septa of No. 2 average less prominent, its calices are smaller, and its structural elements are thinner and otherwise less developed.

(3) Two specimens, southeast reef, line I, 600 feet from shore; water about 7 inches deep at low tide: General characters similar to No. 2, but show complete intergradation with No. 1. In one of the two the septa are thin. The paliform lobes are thin and form irregular plates on one part of the specimen, while on another part, near the edge, they are thick and prominent.

(4) Specimen from 600 to 650 feet from shore; water 8 inches deep; sandy or muddy bottom: A small colony. Calices 2.5 to 3 mm. in diameter. Primary septa thick; pali thick and prominent. Secondary septa well developed; tertiaries variable in development.

(5) Specimen (see plate 84, fig. 1) from southeast reef, line I, 800 feet from shore; water 11 inches deep; bottom hard, rocky: Calices about 3 mm. in diameter; pali usually, but not uniformly, thick and prominent.

(6) Three specimens from southeast reef, line I, 1,000 feet from shore, water 17 inches deep; bottom rocky: Smaller and larger calicled variations occur at the same station; higher cycles of septa more irregular in the smaller-calicled specimen. In one small specimen (see plate 84, fig. 2) nearly all of the bottom of the polypite cavity is filled by the compacted and cemented inner ends of the septa, the prominent pali, and the columella, but the growth-form and scheme of arrangement of the skeletal structures is the same as in the other specimens.

(7) Specimen from southeast reef, line I, 1,200 feet from shore; water 9 inches deep; bottom rocky: Small specimen; calices 2.5 to 3.5 mm. in diameter; pali thick and prominent, usually interfused with the septal ends and columella and the filling occupies most of the bottom of the calice.

(8) Specimen from southeast reef, line I, 1,400 feet from shore; water 14 inches deep; bottom hard, rocky: Calices 2.5 to 3 mm. in diameter; pali usually strongly developed.

(9) Specimen from southeast reef, line I, 1,600 feet from shore; water 10 inches deep; bottom hard. Similar to No. 8.

(10) Two specimens, station on reef not indicated. One of these has calices 2.5 to 3 mm. in diameter; septa average thin and fragile; pali poorly developed. The other specimen shows great variation between its two ends. On one end, calices 3 to 3.5 mm. in diameter; septa thin and fragile; pali indistinct or poorly developed; columella lax, composed of loosely fused irregular trabeculæ. On the other end, calices slightly smaller; septa thicker; pali prominent; septal ends, pali, and columella fused and compacted so as to fill most of the bottom of the calice.

It seems scarcely necessary to summarize into a general description the data given in the preceding descriptions, as that of specimen No. 1 applies to all in its essentials. The principal variation is in the amount of thickening of the skeletal elements and in the degree of development and thickening of the pali.

The following is Bernard's redescription of Quelch's figured type of *Rhodaræa tenuidens*:

"The corallum massive, smooth, oval, apparently built up by successive cushion-like growths (see introduction, p. 24, fig. 2*c*), each consisting of a thick (ca. 2 cm.) layer with bulging sides, and with its edge tending to curl under and not to envelop the whole stock.

"The calices are 3 mm. in diameter, subcircular, with cylindrical fossæ of varying depths up to 3 mm. Wall of unequal thickness, the thinner parts very thin, fragile, and so fenestrated as to form an open lattice-work with frilled ragged edges; the thicker parts, seen from above, are a delicate open reticulum, chiefly confined to their top edges, below which they appear membranous and very porous. Though the tops of the walls are reticular no radial structures can be traced across this reticulum (fig. 7), not even in the shallower calicles at the sides. Within the fossa, however, and below the margin, 24 septal ridges, or rows of short exquisitely fine points, run down the walls. From what appear to be the primaries thin irregularly radial paliform plates rise up, but do not reach to the top of the wall, except in small intercalicular buds. The secondaries (?) are merely rows of long thin spikes, often bent so as to fuse with the primaries. The tertiaries are minute hair-like points, set with broad bases on the wall. The septal formula is obscured. There is often a central tubercle, which in the deep calicles is a medium directive plate. Owing to the rudimentary conditions of the tertiaries the interseptal loculi are conspicuous.

"In the vertical section a striking contrast can be seen between the stout vertical and the horizontal elements of the skeleton. Tabulæ are very numerous.

"The peculiarities of this coral are: (1) the "pulvinate" growth; (2) the neatly circular calicles; (3) the fact that the top edges of the walls are reticular, even though they appear below the edge to remain simple and membranous; (4) the nearly laminate primaries, with their conspicuous but thin paliform plates, which rise to within 1.5 mm. of the mouth of the calicle, except in the shallow lateral calicles and in young buds; (5) the spike-like secondaries and tertiaries, the latter being very minute.

"There is one specimen, an almost symmetrical oval mass, about 9 cm. in long diameter. It is infested with calcareous worms, whose tubes coil among the calicles, and mostly open without bending up free of the surface. For other specimens, showing the same neatly punctured cylindrical calicles and the star-like arrangement of pali, see Table IV, p. 180. They all differ in important points, in depth and size of calices, in the thickness of the walls, in the character of the pali, in method of growth.

"*a.* Zool. Dept. 86, 12.9. 304.

"See pp. 67, 68, 69 for other specimens from Zamboanga, which Mr. Quelch classed under the same name with this coral."

According to Bernard the wall in *G. tenuidens* is not as in these specimens, but his figure (plate 4, fig. 7) does not bear out his statement, as it clearly indicated radial (costal) elements in the wall.

Bernard's scheme of reference to specimen is so peculiar that it is scarcely worth while to try to match other specimens with his descriptions and figures. It is probable that his *Goniopora Great Barrier Reef* (12)4 and (15)5 belong to this species.

Rhodaræa tenuidens as cited by Bedot from Amboina is, I believe, correctly identified.

Distribution.—Great Barrier Reef; Amboina (Quelch, Bedot); off Zamboanga, Philippines (Quelch).

Genus PORITES Link.

1807. *Porites* Link, Beschreib. Natur. Samml. Rostock, p. 162.
1901. *Porites* Vaughan, Samml. Geol. Reichs Mus. Leiden, ser. 2, vol. 2, p. 73.
1901. *Porites* Vaughan, U. S. Commission of Fish and Fisheries Bull. for 1900, vol. 2, p. 314, plate 28.
1902. *Porites* Vaughan, Proc. Biol. Soc. Wash., vol 15, p. 56.
1905. *Porites* Bernard, Porites of the Indo-Pacific Region, pp. 303, 35 plates.
1906. *Porites* Bernard, Porites of the Atlantic and West Indies, pp. 144, 17 plates.

Type species: *Madrepora porites* Pallas[1].

[1]For an account of the restriction of this name, see references to Vaughan's papers cited in the synonymy.

Bernard in his "Porites of the Indo-Pacific" divides the forms of *Porites* from Australia into four subgroups and recognizes the following numbers of variations: Great Barrier Reef, 42; Northeast Australia, 2; North Australia, 8; Northwest Australia, 8. The descriptions are of morphologic variations according to locality, without any attempt to group them into species or to correlate forms found in one area with those found in another, except in a general and rather indefinite way. The work is morphologic, not systematic, and it is a well-nigh hopeless task to group the variations described into a systematic arrangement.

As this is considered the most difficult of coral genera, the technique I use in studying specimens belonging to it will be briefly described. The general morphology of the poritid skeleton has been described by Bernard in two publications[1] and I have considered the subject in two of my papers.[2] These may be consulted for the nomenclature of the different skeletal elements. I have had a number, some thousands, of prints made of the outline diagram represented by figure 2. I begin the study of a specimen by examining it under a binocular microscope to ascertain the septal and palar arrangements, the character and number of the septal granules, and the nature of the wall, after which a diagram of the features is made by filling in a printed outline and it is dropped into the tray with the specimen. After each has been gone over in this way, the specimens are classified, detailed descriptions are written of one or more representatives of each different species, and a tentative synopsis of the specific characters is prepared. The next step is to have enlarged photographs made of the calices; 8 diameters has been found a convenient enlargement. The synopsis is then checked by a study of the photographs and by reference to the specimens. This method apparently promises satisfactory results.

FIG. 2.—Outline diagram of septa in a coral calice.

The number of specific descriptions on this paper is 17, of which 3 are based on Dana's types, and 1 is of a specimen referred by him to *P. conglomerata* (Esper), subsequently made the type of *P. lutea* by Milne Edwards. The number of descriptions of species in my monograph of the Hawaiian Madreporaria is 18, of which 15 are original (entirely or in part) and 3 are quoted. As 3 of the species are common to this and the Hawaiian papers, the two together contain descriptions of 32 species of Indo-Pacific *Porites*. In an account of the Madreporaria collected on the *Albatross* expedition to the eastern tropical Pacific in 1904–1905, I described *Porites paschalensis*[3] from Easter Island, making 33 species of Indo-Pacific species of the genus especially considered by me. As it is important to have information on Dana's types, I list those of his types or original specimens from the Indo-Pacific in the U. S. National Museum and refer to those I have redescribed (see p. 190).

Of 18 species or varieties represented in the collection, I have redescribed and figured 12. I should like to complete describing the collection, but can not do so at present. However, that I have described 12 of the 21 forms of Indo-Pacific *Porites* recognized by Dana may be of some assistance to other students (see table on next page). In my Hawaiian paper I redescribed and figured Verrill's type of *P. tenuis*.

Bernard, notwithstanding his failure to conform to nomenclatorial usage, has aided systematic work on the genus by redescribing and figuring the types of Quelch and of Gardiner deposited in the British Museum (Natural History).

[1]On the structure of Porites, with preliminary notes on the soft parts, Jour. Linn. Soc. London, vol. 27, pp. 487–503, plate 35, 1900; and Porites of the Indo-Pacific region, Cat. of Madrepor. Brit. Mus. (Nat. Hist.), vol. 5, 1905.

[2]Recent Madreporaria of the Hawaiian Islands and Laysan, U. S. Nat. Mus. Bull 59, pp. 169–217, 1907; and H. M. Bernard's work on the poritid corals [review], Science, n. s., vol. 26, pp. 373–378, Sept. 20, 1907.

[3]Bull. Mus. Comp. Zool., vol. 50, pp. 71–72, plates 9, 10, 1906.

Von Marenzeller, in his work on the *Pola* expedition corals, has published valuable critical notes on *Porites solida* (Forsk.),[1] but unfortunately does not figure the type. Gravier in his "Les récifs de coraux et les madréporaires de la baie de Tadjourah"[2] describes as new *Porites somaliensis*, with which I am identifying a species collected in Cocos-Keeling Islands by Dr. Wood Jones.

The foregoing brief statement indicates that systematic knowledge of the species of *Porites* and their geographic distribution is gradually increasing.

There is a large quantity of unstudied material in the U. S. National Museum, including especially the collection made on the *Albatross* expedition to the tropical Pacific in 1899–1900 and very large collections from the Philippine Islands. I hope I may be able to describe these collections. By working over large collections in conjunction with a study of Bernard's "Catalogue," I believe it possible to make valuable use of his work.

Dana's types and original specimens of Indo-Pacific species of Porites in the U. S. National Museum.

Name.	U. S. Nat. Mus. No.	Described Bull 59, U. S. Nat. Mus.	In present paper.	Not re-described.
P. compressa Dana	711	×	..	.
cribripora Dana?	670	..	..	×
cylindrica Dana	708	..	×	
favosa Dana	672	..	(*a*)	.
fragosa Dana	643	.	×	.
lichen Dana	666	×	..	..
limosa Dana	673	..	×	..
lobata Dana	652	×	..	.
conglomerata Dana	683	..	(*b*)	..
mordax Dana	710	×	..	..
mordax var. elongata Dana	707	(*c*)	..	..
mucronata Dana	689	..	..	×
nigrescens Dana	691	..	×	..
palmata Dana	689	..	..	×
reticulosa Dana	663	×	..	..
(Synaræa) contigua Dana = danæ Verrill	684	..	..	×
(S.) erosa Dana	668	..	..	×
(S.) monticulosa Dana	664	..	..	×

a Under *P. lobata*. *b* As *P. lutea* M. Ed. *c* As var. of *P. compressa*.

Key to species of Porites described in this paper.

Corallum massive, rounded or lobulate.
Without pronounced horizontal thickening of skeletal elements.
Inner ends of members of triplet free, without trident formation.
Pali smaller than the septal denticles, or only slightly larger.
Wall thin, calices, 1.5 to 2.5 mm. in diameter, rather deep, inner ring of plate-like denticles, pali weakly developed .... 1. *P. solida* (Forsk).
Wall rather thick, rough, often trimurate; calices usually 1.5 in diameter, excavated, septal denticles thicker and rougher than in 1; pali, formula complete, less prominent or only slightly more prominent than the septal denticles .... 2. *P. lobata* (Dana)
Wall thick, rough; calices deep, funnel-shaped, 1 to 1.5 mm. in diameter, septa rather thick; pali poorly developed except near edge of the corallum .... 3. *P. murrayensis* new species
Pali before the directive septa and laterals of the triplet smaller than the septal denticles, those before the lateral pairs often more prominent.

[1]Denksch. k. k. Akad. Wien., vol. 80, p. 65, 1906.
[2]Ann. Inst. Oceanograph., vol. 2, fasc. 3, p. 80, plate 11, figures 46–48, 1911.

Wall ridge definite, often zigzag, mural denticles coarse, roughly frosted; calices deep, 0.8 to 1.5 mm. in diameter; septa wedge-shaped; columella a deep seated, compressed rough style...4. *P. fragosa* Dana.
Pali, especially those before the lateral pairs of septa, larger than the septal denticles.
Wall, a ridge or trimurate, in the latter condition mural trabeculæ obvious; mural denticles coarsely granulate; calices shallow or excavated.....................5. *P. australiensis* new species.
Wall relatively wide, crossed by radial costæ; calices excavated..............6. *P. mayeri* new species.
Inner ends of members of triplet form a trident.
Wall straight, mural denticles delicately frosted; calices shallow; corallum more or less lobulate...7. *P. haddoni* new species.
Wall thin, straight, mural denticles more coarsely granulate than in 7; calices excavated except near edge of the corallum; corallum hemispherical..............8. *P. somaliensis* Gravier.
Wall zigzag, often interrupted, relatively coarse; corallum subspherical, surface undulate.
9. *P. lutea* M. Edw.
Without greatly pronounced horizontal thickening of the skeletal elements, but with considerable development of twisted and curved flake-like septal processes; septa crooked; septal granules and pali as irregular knots.
Calices large, up to 2 mm. in diameter; triplet with trident formation; columella more or less attached to the directive of the triplet..................................10. *P. limosa* Dana.
With pronounced horizontal thickening of the skeletal elements, producing a flaky appearance.
Calices excavated, septal margins sloping, corallum with rounded lobes and flat-topped gibbosities...11. *P. viridis* Gardiner.
Calicular fossæ, pits sunk between wide mural reticula; upper surface of corallum rounded, without gibbosities...12. *P. densa* new species.
Corallum composed of columniform lobes.
Calices excavated; palar formula complete (calicular characters closely similar to those of *P. lobata*)...13. *P. pukoensis* Vaughan.
Corallum a thin attached lamina.
Asexual reproduction often by fission, some calices form series..................14. *P. lichen* Dana.
Corallum ramose.
Walls flaky, interseptal loculi narrow.
Usually 2 septal granules; calices shallow or superficial.
Pali and septal granules prominent..................................15. *P. andrewsi* new species.
Pali and septal granules not so conspicuous as in 15.........................16. *P cylindrica* Dana.
Normally 1 septal granule which is remote from the palus; calices slightly excavated..17. *P. nigrescens* Dana.

1. Porites solida (Forskål) Klunzinger.

Plate 84, figures 3, 3*a*, specimen from Cocos-Keeling Islands.

1879. *Porites solida* Klunzinger, Korall. Roth. Meer., pt. 2, p. 42, plate 5, fig. 21; plate 6, fig. 14.
1905. *Porites erythrææ prima* Bernard, Cat. Porites Indo-Pacific, p. 236, plate 33, fig. 7.
1908. *Porites solida* von Marenzeller, Denksch. k. k. Akad. Wiss. Wien, vol. 80, p. 65.
1910. *Porites* Wood Jones, Coral and Atolls, p. 76, text-fig. 14.

The following is a description of a specimen of *Porites solida* from Cocos-Keeling Islands:

Corallum with a widely expanded incrusting base, above which it thickens and forms a mass with a hillock surface. Diameter up to 18 cm.; thickness up to 7 cm.

Calices polygonal, excavated, relatively deep. Diameter, 1.5 to 1.75 mm. in depressions; up to 2.25 mm. on tops of hillocks; nearly 2 mm. is a frequent size.

Walls tall, straight, perforate, membraniform, in places a slight development of intermural reticulum. Mural denticles about twice as numerous as the septa, erect, frosted rods, which may be compressed radially or in plane of wall.

Septa of medium thickness, about as thick as the width of the interseptal loculi, faces densely granulate. There are the usual number, a solitary directive, 4 lateral pairs, and a triplet, with the inner ends of its members free from one another. The septa begin some distance below the upper edge of the wall. Septal trabeculæ form rather obscure septal denticles, which are only slightly distant from the wall; outer synapticular ring close to the wall and incomplete.

The pali in this species are peculiar. Within the septal denticles already noted there is a thin plate-like lobe or denticle on each of the 12 septa, and these lobes form a more or less definite ring, simulating pali, but on the lateral pairs they stand outside the points of fusion, while in some instances erect, thin, but not very tall pali actually occur at the point of fusion of the laterals. This ring therefore represents an inner ring of septal

trabeculæ.[1] The pali are weakly developed, or even absent; sometimes 4, those before the lateral pairs, are present; occasionally there is one before the solitary directive, and very rarely is there a suggestion of a palus on the members of the triplet.

Columella tubercle is a lamella lying in the plane of the directive septa and joined to them; also joined by radii to the lateral pairs and to the laterals of the triplet. There may be considerable compacting of the tangle.

Habitat, etc, Cocos-Keeling Islands.—Dr. Wood Jones states: "Very abundant and an important constituent of all composite rocks and of breccias. Color the same as in [*P. somaliensis*]."

Bernard has made comparative notes on those of the Red Sea forms of *Porites*, which he designates Red Sea (9)1 (the species here described), (9)2, and (9)8. The types of four of the massive species described by Dana from the Fiji Islands are in the U. S. National Museum; *P. conglomerata* (=*P. lutea* M. Edw.), *P. fragosa*, *P. favosa*, and *P. limosa*. They are markedly different from *P. solida*.

Distribution.—Red Sea; Cocos-Keeling Islands.

2. Porites lobata Dana.

Porites lobata forma centralis Vaughan.

Plate 85, figures 2, 2*a*, 3, specimen from Fanning Island.

1907. *Porites lobata* forma *centralis* Vaughan, U. S. Nat. Mus. Bull. 59, p. 201, plate 82, fig. 2; plate 83, figs. 2, 2*a*; plate 84, figs. 1, 1*a*, 1*b*, 2; plate 85, fig. 1; plate 96, figs. 1–3.

Two specimens brought by Mr. Elschner from Fanning Island are in the U. S. National Museum. I subdivided forma *centralis* into five subformæ and designated them *alpha*, *beta*, *gamma*, *delta*, and *epsilon*. One of the Fanning Island specimens (see plate 85, figs. 2, 2*a*) is subforma *beta*, in which "the living layer is bent under and creeps over a portion of the base." The other specimen is subforma *gamma;* its calices are represented by plate 85, figure 3.

As it seems to me that Dana's *Porites favosa* is surely a synonym of *P. lobata*, I am introducing figures of it (plate 85, figs. 1, 1*a*) and a few notes on the type:

Porites favosa Dana (type No. 672, U. S. Nat. Mus., plate 85, figs. 1, 1*a*): Calices from 1.25 to 1.5 mm. in diameter, except in depressions, where they may be only 1 mm. across. The wall forms a distinct elevated ridge. The pali are small, but the formula is normally complete. The figures show the essential details and they may be compared with those contained in my paper on the Hawaiian corals cited in the synonymy.

Distribution of Porites lobata.—Hawaiian Islands; Fanning Islands; Fiji Islands.

3. Porites murrayensis, new species.

Plate 84, figures 4, 4*a*, 4*b*, 5, specimens from Murray Island. Also plate 13, figures 12, 14, of Dr. Mayer's article.

The following is a description of this species:

Corallum massive, form hemispherical or subspherical, with attachment on a part of the periphery; surface uniformly rounded or with variously shaped undulations.

Calices deep, axial fossa a pit; diameter, usually 1 to 1.5 mm.; in depressed areas somewhat less.

Wall rather thick, elevated, fairly continuous, interrupted in places, usually straight, occasionally shows zigzagging. Denticles along its upper edges not uniform; on some parts of the surface there are about twice as many as the septa, where they may be compressed in radial planes; in other areas they may be tangentially compressed. The denticles are beset with divergent granulations.

Septa 12 in number, rather thick, interseptal loculi of the same width or somewhat wider or narrower than the thickness of the septa. Septal faces beset with granulations

[1]See Bernard's description *Porites solida* (Forskål) Klunzinger, Cat. Porites Indo-Pacific, p. 237.

which restrict the interspaces. Outer septal ends sometimes joined to the wall by forks. Margins, except near the lower edge, slope steeply to the palar ring, inside which there is a vertical drop to the bottom of the columellar pit.

Outer synapticular ring usually well developed, with a ring of denticles corresponding to its inner edge. In places this ring may be so developed as to produce a trimurate condition. The synapticular palar ring is deep-seated, and, although usually complete, may sometimes be discontinuous.

Palar formula normally complete, the members of the triplet always free from one another. The pali usually poorly developed, but near the lower edge they may be prominent. Those before the lateral pairs the more prominent; those before the solitary directive and the members of the triplet less developed, barely indicated, or suppressed. They are as granulate as the septa. Frequently there are 1 or 2 smaller processes between the pali and the outer synapticular ring, but they probably are radial projections from the outer septal trabeculæ and do not represent trabecular ends.

Columellar tubercle weakly developed or entirely absent, the inner ends of the septa forming a deep-seated columellar tangle.

The foregoing description applies particularly to the calices on the sides and upper surface of the corallum, somewhat distant from the edge of the living part. Near the edge of the living tissue the calices are shallower, the pali well developed, rather tall, and a conspicuous, compressed columellar tubercle is often present.

Stations, Murray Island.—Southeast reef, line I:

400 feet from shore; depth of water, 4.5 to 5 inches.
600 feet from shore; depth of water, 15 inches; bottom sandy (type specimen, plate 84, figs. 4, 4*a*, 4*b*).
650 feet from shore; 5 to 10 inches deep; bottom, sandy.
1,000 feet from shore; water 15 inches deep; bottom hard, with a little sand (see plate 84, fig. 5).
1,220 feet from shore; depth of water, 16 inches; bottom hard, rocky.

The 6 specimens of this species exhibit no marked differences among themselves in calicular characters. There is the variation in form noted in the first sentence of the description.

I have been unable to identify this species with any of those recorded by Bernard from the Great Barrier Reef. Its characters may be summarized as follows: growth-form massive; calices with deep fossa, 1 to 1.5 mm. in diameter; wall elevated, interrupted in places; pali, the formula complete, or reduced on the directives and on the laterals of the triplet; columellar tubercle frequently absent. Other details are given in the description. The species groups with *P. australiensis*, new species, but differs from the latter by its deeper calices and less developed pali and columellar tubercle. It is so very close to *Porites brighami* Vaughan,[1] from the Hawaiian Islands, that I am not positive that they are distinct. Both have deep, funnel-shaped calices, and usually weak pali, but which when fully developed are according to the complete formula. The wall of *P. brighami* is more ragged, and combined with the outer synapticular ring it is more compact than in *P. murrayensis*, In none of the suite of the former in the U. S. National Museum are the pali and columellar tubercle prominent in the calices near the lower edge of the living tissue; while in the latter the reverse is true. In *P. brighami* there are usually 4 or 5 minute processes on the septal margins between the pali and the outer synapticular ring, a larger number than on *P. murrayensis*, which may have one or two such minute projections. For these reasons, although closely related, they appear to represent different species.

P. murrayensis and *P. brighami* furnish additional evidence of the Indo-Pacific affinities of the Hawaiian Madreporarian fauna.

Distribution.—Torres Strait.

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[1] U. S. Nat. Mus. Bull. No. 59, p. 208, plate 84, figs. 3, 3*a*.

4. Porites fragosa Dana.

Plate 86, figs. 2, 2*a*, Dana's type of the species.

1846. *Porites fragosa* Dana, U. S. Expl. Exped., Zooph. p. 563, plate 55, figs. 9, 9*a*.
1905. *Porites fidjiensis undecima* Bernard, Cat. Porites Indo-Pacific, p. 52.

The following is a description of Dana's type of *Porites fragosa*:

Corallum relatively heavy; surface glomerate, irregularly ridged; type 20.5 by 22 cm. in horizontal diameter and 26 cm. tall.

Calices in neat polygonal patterns; larger ones, 1.5 mm. in diameter; smaller ones in depressions about 0.8 mm.; excavated, but the pali stand up above the columella.

Wall, a distinct ridge, often zigzag; mural denticles rather coarse, coarsely frosted, about twice as many as the septa.

Septa rather thick, wedge-shaped, sides coarsely granulate; formula complete. Either one or two denticles between the pali and the wall, two often present. The outer denticle, where two are present on a septum, the single one where there is only one, is detached from the wall; it occurs lower than the mural summit and often above the tops of the pali. Where there are two denticles the outer is often at a higher level than the inner. The pali rise higher than the intermediate septal denticles, and, although usually lower, they sometimes rise higher than the outer denticles, but rarely or never reach so high as the mural summits. The columellar fossa is deep and is bounded by the inner edges of the pali. From these relations it will be evident that usually there is a slope from the upper edge of the wall to the outer palar margins; then a rise over the palus, but usually not to the level of the top of the outer septal denticles, and a sudden drop of the inner palar margins to the bottom of the columellar fossa.

The outer synapticular ring is rarely or never complete; synapticular processes usually run from the mural to the outer septal trabeculæ. However, occasionally an outer synapticular ring is developed on some sides of a calice. The palar ring of synapticulæ is deep seated, and often appears incomplete, *i.e.*, it is so deep down in the calices that it can not be positively recognized by looking downward into them.

Pali normally in the complete formula, but those before the lateral pairs are pronouncedly more prominent than those before the other septa. The laterals of the triplet converge, but they seem never to fuse in a group, nor is there any suggestion of trident formation. The wedge-shape of the solitary directive and of the members of the triplet is very striking. The palus on the directive of the triplet often stands farther outward than those on the laterals of the triplet. Their sides are roughly granulate.

The columella is a compressed, roughly granulate tubercle, situated in a deep pit and joined by radii to the inner margins of the septa.

Type: No. 643, U. S. Nat. Mus.

Locality.—Fiji Islands (U. S. Expl. Exped.).

This species of course groups with those which form massive coralla and have the pali in the complete formula. The pali on the directives and the laterals of the triplet are narrower, thinner, and lower than the septal denticles. These characters, taken in conjunction with the definite wall-ridge, wedge-shaped septa, deep columellar fossa in which is a coarsely granulate, deep-seated columellar tubercle, and the deep-seated ring of palar synapticulæ, distinguish it from any other species here considered. I do not positively recognize it as any of the forms figured by Bernard.

5. Porites australiensis, new species.

Plate 85, figures 4, 4*a*, 5, 6, 6*a*, specimens from Murray Island. Also plate 13, figure 13; plate 14, figure 15, of Dr. Mayer's article.

1905. *Porites queenslandiæ none et vicesima*, Bernard, Cat. Porites Indo-Pacific, p. 132, plate 17, figs. 3, 4, 5; plate 21, fig. 21.

The following is a description of the type of this species:

Growth-form massive, somewhat flattened above, domed, subhemispherical, or spherical; surface gradually curved or slightly undulate.

Calices shallow; diameter, measured between mural summits, 1 to 1.5 mm.; about 7 calices in a distance of 1 cm.

Walls usually straight, rarely zigzag, composed of vertical trabeculæ joined by synapticulæ into a ring. The trabeculæ terminate in prominent rough granulate mural denticles, of which there are about twice as many as there are septa. The denticles, when extended, are parallel to the septal planes. The granulations divergent.

Septa 12 in number, rather thick, interseptal loculi usually narrower than the septa, the restriction mostly due to the relatively large septal granulations. Usually two synapticular rings within each calice. Above the outer ring is a ring of irregularly shaped, granulate septal denticles. Between these and the wall the outer ends of the septa are usually bifurcate, each limb of the fork corresponding to a mural denticle. The inner synapticular ring corresponds in position to the pali. The palar formula is normally complete, *i. e.*, one on the solitary directive, one on each member of the triplet, rarely with suggestions of trident formation, and one at the fusion of the lateral pairs. Those before the lateral pairs are the more prominent; they are tall, reaching almost to the level of the upper edge of the wall, erect, slender, and roughly granulate. The other pali are lower and smaller. The directive of the triplet is usually shorter than the lateral members, and the palus on it stands back slightly. Between the palar trabeculæ and the outer septal denticle an intermediate denticle is usually on each member of the lateral pairs and sometimes on the solitary directive and each member of the directive triplet. The single septal denticle or the outer one, where two are present, is only slightly detached from the wall.

In places the outer synapticular ring is highly developed and the mural trabeculæ thickened, thus producing the appearance of a rather wide, reticulate wall.

The columella is an erect, narrow plate, roughly granulate, joined to the septal ends by radii, frequently 5 in number, between which the spaces are narrow but open.

The preceding description, except of the growth-form, is based on one specimen (see plate 85, figs. 4, 4*a*). The principal variations within the colony consist in the degree of the development of the outer synapticular ring and whether the outer septal denticles are below or flush with the upper edge of the wall, producing respectively the appearance of narrow, simple walls or of wide, reticular walls. It may be added of the aspect of the corallum that under a binocular microscope the texture is coarse; the granulations are greatly developed and restrict the interseptal and other spaces.

Stations, Murray Island.—Southeast reef flat, line I:

450 feet from shore; water about 6 inches deep.
550 feet from shore; water about 8 inches deep; coral sandy bottom.
620 feet from shore; water 10 inches deep at low tide; bottom sandy (type specimen, see plate 85, figs. 4, 4*a*).
675 to 720 feet from shore; water 12 inches deep.
800 feet from shore; water about 11 inches deep; hard, rocky bottom.
1,000 feet from shore; water about 15 inches deep; bottom hard rock with some sand.
1,200 feet from shore; water about 9 inches deep; rocky bottom.
1,400 feet from shore; water 14 inches deep; hard, rocky bottom.
Lithothamnion ridge, 1,720 to 1,775 feet from shore.

The variation in form was noted in the first sentence of the description, and most of the other variation is shown on the described specimen. On the specimens 1,200 feet from shore some of the calices near the lower edge are 2 mm. in diameter (plate 85, fig. 5), and the intervening walls are raised and thin, but the calices are shallow. On top of the corallum the calices are 1.5 mm. in diameter. A specimen (plate 85, figs. 6, 6*a*), 800 feet from shore, has calices frequently slightly less than 1 mm. in diameter; the walls usually are simple, but in places are reticular, especially in the angles; and the columellar tubercle is less prominent than on the average in other specimens. Notwithstanding the variations noted, the essential characters are uniform. As they are expressed in the description they will not be summarized.

Bernard's *Porites Great Barrier Reef* (42)34 almost certainly also belongs to this species, and perhaps other morphologic variations described by him.

Distribution.—Torres Strait; also at Nasugbu, Luzon, Philippine Islands, *Albatross*, 1908. The intermediate septal denticles of the latter specimens average taller than in those from Murray Island.

6. Porites mayeri, new species.

Plate 86, figures 1, 1*a*, 1*b*, specimen from Murray Island. Also plate 13, figures 9, 10, 11, of Dr. Mayer's article.

1905. *Porites queenslandiæ secunda et tricesima* Bernard, Cat. Porites Indo-Pacific, p. 136, plate 17, fig. 8; plate 21, fig. 23.

The following is a description of this species:

The corallum has an incrusting base, above which it rises into a mass with gibbosities and irregular lobes and ridges, but does not form plates. The lower edges frequently show successive incrustations, one above another. Occasionally a colony may be rather regularly rounded, *i. e.*, without the gibbosities.

Calices conspicuous, excavated, polygonal or subcircular; large, diameter 1.5 to 2 mm., an intermediate size the more usual, except in the bottoms of depressions, where it may be 1 mm. or less.

Walls present two aspects: (1) On the sides, near the tops of lobes, the mural trabeculæ may be distinct, but even here they are compressed in planes transverse to the walls; they are joined by concentric bars; (2) the mural trabeculæ are scarcely distinguishable in a reticulum composed of projecting, interrupted, plate-like, radial structures joined together by concentrically arranged synapticulæ. The top of the reticulum may be flat.

Septa 12, 4 lateral pairs, solitary directive, members of the triplet separate from one another. Outer zone of synapticulæ well developed, with a ring of prominent, rough, irregularly shaped denticles rising above it. Outside this synapticular zone the septal ends are usually bifurcate, sometimes trifurcate, and are continued into the radial structures which extend to or even across the wall and combined with it build the reticulum already noted. Usually the palar formula is complete, the pali on the solitary directive and the members of the triplet being well developed; but those before the lateral pairs average taller, somewhat thicker, and reach nearly to the level of the wall. The palar ring of synapticulæ is irregularly developed, usually incomplete. Often there is between a palus and the outer synapticular ring a well-developed denticle, which appears to represent the emergent end of a trabecula. The septa are composed of inwardly inclined trabeculæ, which in places result in a denticle intermediate between the synapticular rings. Septal faces rough, but the interseptal loculi are rather open, the openness being increased by the incompleteness of the palar synapticular ring.

A weak columellar tubercle persistently present. It is usually compressed in the plane of symmetry and attached to one or the other or both directive septa. Columellar tangle variable in development, lax or fairly compact.

Stations, Murray Island.—Southeast reef, line I:

600 feet from shore; water 15 inches deep; sandy bottom.
650 feet from shore; water 18 inches deep; rocky bottom.
675 to 720 feet from shore; water 12 inches deep.
800 feet from shore (type); water 11 inches deep; bottom hard, rocky.
1,000 feet from shore; water 17 inches deep; bottom rocky.
1,200 feet from shore; water 9 inches deep; bottom rocky.
1,220 feet from shore; water 14 inches deep; sandy bottom.
1,400 feet from shore; water 14 inches deep; bottom hard, rocky.
1,600 feet from shore; water 10 inches deep; bottom hard, rocky.

As Bernard has pointed out, his *Porites Great Barrier Reef* (42)39 is probably the same as this species, but as I am not positive it is omitted from the synonymy.

There are 13 specimens of this species, furnishing a fairly satisfactory suite. Except in form almost the extremes of variation are shown in the two specimens from 800 feet from shore; one of these is the type (see plate 86, figs. 1, 1*a*, 1*b*), on which the detailed description is based; the other is the variant. The nature of the variation, as has been indicated, consists in the degree of the development of the intercalicular reticulum. The variant referred to usually has a distinct elevated

wall; along its summit are projecting trabeculæ, which, however, are radially compressed. The wall is straight, not zigzag. Where these conditions occur there is usually a well-developed mural shelf below the upper edge of the wall. As in places there is an intercorallite reticulum, it is not practicable to recognize two species. The specimens from 1,400 and 1,600 feet from shore show a great development of the reticulum which may well up in the angles between calices or form low, curved ridges. The close similarity of *P. mayeri* and *P. viridis* is discussed on page 201. Larger suites of specimens may show that the two forms are really only variants of one species.

Distribution.—Torres Strait.

7. Porites haddoni, new species.

Plate 87, figures 1, *1a*, *1b*, specimen from Murray Island.

1905. *Porites queenslandiæ tertia et vicesima* Bernard, Cat. Porites Indo-Pacific, p. 127, plate 16, fig. 4; plate 21, fig. 13.

1905. *Porites queenslandiæ tricesima* Bernard, Cat. Porites Indo-Pacific, p. 134, plate 17, fig. 6; plate 21, fig. 22.

The following is a description of this species:

Growth-form, rising from a small base, expanding and massive above, with radiating rounded ridges and intervening depressions. Type specimen about the size of a man's fist.

Calices polygonal, shallow; usual diameter on upper surfaces 1 to 1.5 mm., 8 to 10 calices to 1 cm.; in depressions, diameter slightly less than 1 mm.

Walls, straight, narrow, membranous, continuous, but with perforations; denticles along summit indefinite, often compressed parallel to the mural plane, about twice as numerous as the septa. Surfaces delicately spinulose.

Septa 12 in number, fairly thick; as thick as, or somewhat thicker or thinner than the interseptal loculi. Surfaces closely beset with granulations which restrict the interspaces. Two synapticular rings within each calice. The outer, which is near but usually detached from the wall, varies greatly in completeness on different parts of the corallum. On the lower part of the corallum it may be highly developed and surmounted by pronounced outer denticles, between which and the wall is a definite excavated ring. The outer ends of the septa between the denticles and the wall are frequently bifurcate. On other parts of the corallum, although the outer synapticular ring is represented, it is only slightly developed and does not form a mural shelf. Here the condition is similar to Bernard's plate 17, figure 6. The inner synapticular ring corresponds in position to the pali. The palar formula may be complete, *i. e.*, one on the solitary directive, one on each member of the triplet, and one at the fusion of each lateral pair; or the pali may be suppressed on the laterals of the triplet, sometimes suppressed on the ventrical directives, and frequently there are 6 pali, when trident formation may be obvious. Those before the lateral pairs are the more prominent, reaching to or almost to the level of the upper edge of the wall; they are slender and closely granulate. The other pali are shorter and not so thick, but also densely granulate. Sometimes, but not invariably, there is a denticle between the outer denticle and the palus.

The columella is an erect, narrow, densely granulate plate, joined to the septa by radii, between which the spaces are narrow, but usually open, except near the lower edge of the living tissue.

Stations, Murray Island.—Southeast reef, line I:

400 feet from shore; water about 5 inches deep.
600 to 1,000 feet from shore; water about 10 inches deep.
650 feet from shore; water about 11 inches deep.
675–720 feet from shore, water about 10 inches deep; bottom sandy, with coral rock (type).

This species differs from *P. australiensis* by its membranous wall, the more delicate frosting of the mural denticles, the more definite detachment of the septal denticles from the wall, the presence of trident formation in the triplet, and its lobate growth-form. Bernard pointed out that his *P. Great Barrier Reef* (42)23 and (42)30 might belong to the same species.

8. Porites somaliensis Gravier.

Plate 87, figures 2, 2*a*, 2*b*, specimen from Cocos-Keeling Islands.

1911. *Porites somaliensis* Gravier, Ann. Inst. Oceanograph., vol. 2, fasc. 3, p. 80, plate 11, figs. 46–48.

This species is represented by one small specimen and fragments of two large ones. As the succeeding description is based on all the material and is supplemented by a photograph by Dr. Wood Jones, it is composite.

Corallum forms subspherical heads truncated on the lower surface where attached; some radiating swellings and intervening depressions. Diameter up to 17 cm; height, up to 12 cm.

Calices polygonal, distinct, superficial near lower edge of living tissue, deeper on upper portion of corallum. Diameter from 1 to 1.5 mm., usually about 1.25 mm.

Wall straight, thin, continuous or interrupted, usually with about twice as many erect, frosted denticles as there are septa. The denticles are frequently compressed in radial planes, but sometimes are irregularly shaped, frosted rods. In places on the upper surface the denticles are small, irregular, and only slightly prominent.

The septal arrangement and structure is constant for all parts of the corallum, but there is considerable variation in thickness of the skeletal elements, the development of the septal denticles, and the depth of the calices. There are the usual 12 septa, which are arranged into a solitary directive, 4 lateral pairs, and a directive triplet, the lateral of which are not fused by their inner ends, but are fused by a transverse membrane which rises above the level of the columellar tangle, resulting in a trident (according to the terminology proposed by Bernard). Between each palar trabecula and the wall is a single septal trabecula which usually forms a distinct septal denticle (granule) detached from the wall. Between the granule and the wall the ends of the septa are usually bifurcate. The septal faces are granulate. This scheme is constant.

On the upper surface the septa are thin, less than half as thick as the width of the interseptal loculi; they begin an appreciable distance below the upper edge of the wall. The septal denticles are not prominent, are irregular in shape, and the outer synapticular ring is imperfectly developed. The pali on the inner ends of the lateral pairs are tall, reaching the level of the upper edge of the wall, erect, and slender; the other pali are variable in development or absent, more often developed on the two directives than on the laterals of the triplet, but occasionally present on one or both of the latter. The transverse membrane joining the inner ends of the triplet to one another has been mentioned.

Near the lower edge of the living tissue the calices are shallow, the septa are thick, densely beset with spinulose granulations, and the interseptal loculi are narrow. The septal denticles are detached from the wall and so tall that they reach the level of the mural edge. Occasionally two septal denticles are present, the inner being the smaller. The outer synapticular ring is not always complete, but is more developed than on the upper surface. There are usually 6 pali which reach the same level as the wall and the septal denticles, but there is marked variation in the triplet, on which there may be 1, 2, or occasionally 3 pali; when 2 are present usually it is the one on the directive which is suppressed.

The palar ring of synapticulæ is nearly or entirely complete; it, with the compressed columellar tubercle and the radii joining the latter to the inner ends of the septa, forming the columellar tangle. The top of the tubercle is well down within the calices on the upper surface, but is prominent near the edge of the living tissue.

Habitat and color, Cocos-Keeling Islands.—Dr. Wood Jones states:

"The most abundant coral in the atoll, the one that by its dead remains forms the bulk of the solid material of the dry land. The specimen is from the barrier. The color varies from purple, purple brown, olive brown, olive green, and yellow brown to yellow."

Porites somaliensis has a suggestive resemblance to *Porites lutea* M. Edw. from the Fiji Islands, notes on the type of which immediately follow.

Distribution.—East coast of Africa; Cocos-Keeling Islands.

9. Porites lutea Milne Edwards.

Plate 88, figures 1, 1*a*, 1*b*, type of species, the specimen identified by Dana as *Porites conglomerata*.

1846. *Porites conglomerata* Dana, U. S. Expl. Exped., Zooph., p. 561, plate 55, figs. 3, 3*a*.
1860. *Porites lutea* Milne Edwards, Hist. nat. Corall., vol. 3, p. 180.
1905. *Porites fidjiensis secunda* Bernard, Cat. Porites Indo-Pacific, p. 44, plate 3, figs. 1–4; plate 11, fig. 3.
1905. *Porites fidjiensis decima* Bernard, Cat. Porites Indo-Pacific, p. 52 (see also p. 244).

The specimen referred by Dana to *Porites conglomerata* (Esper) is in the U. S. National Museum, No. 683. Basing an inference on Bernard's account[1] of *Porites lutea*, this specimen is the type of the species.

P. lutea has a corallum nearly enough like that of *P. somaliensis* for them to be considered of the same growth-form, the calices are of about the same size, the septa, palar rings, and septal denticles are similar, and they both have the peculiar junction of the members of the triplet by a membrane tranverse to the septal planes. The palar arrangement also seems similar, but the walls appear to be persistently different. That of *P. lutea* is zigzag, interrupted, and ragged, and in places near the lower edge it is obscure. The skeletal surfaces of *P. lutea* are not so conspicuously and roughly granulate as *P. somaliensis.*

The following are Bernard's introductory notes on and description of his *Porites fidjiensis secunda:*[2]

"Under this heading I propose to group four specimens; in spite of remarkable differences in habit, they all have the same essential structure of calicle, and apparently the same growth-form.

"*Description.*—The corallum is massive; its surface breaks up into lobules which are fairly uniform in size and shape, about 2 to 2.5 cm. across, and showing a slight but distinct tendency to be bluntly ridged, rather than round-topped. The valleys between the lobules are shallow, except where three meet, when they dip down steeply into small hollows 1 cm. deep.

"The calicles vary on the different specimens from 1 to 1.5 mm. The walls all show a sharp, thin median ridge of fused trabeculæ, which rise to different heights; they are highest when the calicles are small and alveolate, lowest when the latter are large and shallow. On each side of the median ridge there is a ring of granules or flakes; in cases in which the calicles are small and deep and the skeleton light, these are seen to be the septal granules, but the whole aspect of the calcicle changes when they are broad and flaky, as in the larger shallower calices; they then form together a broad platform all round, just beneath the top of the median ridge. The septal formula is always complete (fig. 3, B); the four principal pali are very large. The ventral directive is continued into a keel, which, deep down in the fossa, represents a flattened central tubercle. On each side of this long directive the free septa bend sharply round just below the pali to form with it a trident. Still deeper down a clear columellar ring can be generally made out, with a varying number of attachments to the centre."

Other areas which would more nearly duplicate Bernard's figures, especially his plate 3, figures 2 and 3, might have been selected on Dana's specimens.

Distribution.—Fiji Islands.

10. Porites limosa Dana.

Plate 88, figures 2, *2a*, Dana's type of the species.

1846. *Porites limosa* Dana, U. S. Expl. Exped., Zooph., p. 563, plate 55, figs. 2, *2a*.
1905. *Porites fidjiensis quarta* Bernard, Cat. Porites Indo-Pacific, p. 46, plate 3, figs. 6, 7.

The following is a description of Dana's type of *Porites limosa:*

The type specimen had a layer of living coral growing over a base of dead coral belonging to the same species. Surface of corallum glomerate.

Calices large, often 2 mm. in diameter, the small ones in depressions 1.25 mm. in diameter. Although excavated, in comparison with their width they are rather shallow.

The wall forms a distinct, sharp ridge, where the surface of the corallum has not been damaged. It is decidedly and irregularly perforate near the edge, but in places it may extend the length of a side of a calice as a continuous sharp edge. Mural denticles are coarse and irregular. There are almost no small granulations, the surface usually having a more or less glassy appearance.

[1] *Op. cit.*, p. 244. [2] Bernard, Cat. Porites Indo-Pacific, p. 44, 1905.

The septa occur in the complete formula, but present an indefinite appearance, as they are very crooked. There are trabeculæ producing septal granules below the upper edge of the wall, while curving, flattish processes join the septal trabeculæ to both the wall and palar trabeculæ and also to the septal trabeculæ of other septa. The flattening of the processes is not in any one plane; in some places it is horizontal, in others vertical, and in others at varying angles. Although the result is a more or less flaky texture, it is very different from that found in *P. nigrescens*, where there are horizontal or subhorizontal, flattish, wedge-shaped processes, arranged vertically one above another along the septal plane. Because of the development of the septal trabeculæ, especially where the calices are large and there are two septal outside the palar trabeculæ, the processes from the septal and the mural trabeculæ form a perforate mural reticulum.

Pali small, irregular knots on the inner ends of the septa. The formula is complete, but with a pronounced tendency toward trident formation in the triplet. The palar trabeculæ are joined by more or less flattened and twisted processes into a ring and similar processes join them to the columella.

A striking peculiarity of the mural, septal, and palar faces and the processes from them is the fewness of small granulations or frostings, producing smoothish skeletal surfaces.

The columella is a twisted lamella, usually showing attachment to the directive member of the triplet.

Type: No. 673, U. S. Nat Mus.

Locality.—Fiji Islands (U. S. Expl. Exped.).

Distribution.—This species is the same as Bernard's *Porites Fiji Islands* (24)4, which is Gardiner's *Porites trimurata*, from Wakaya Reef lagoon, Fiji Islands, and is probably the same as Gardiner's *Porites trimurata* from Funafuti lagoon.[1] Bernard says regarding the latter specimens:[2]

"Mr. Gardiner has called attention to the close similarity between *P. Fiji Islands 4* and this coral by uniting them under one specific name: '*trimurata*.' . . . The calices of the two forms are built on the same essential plan, but are larger in the Fiji form, and the rings of pali are not so conspicuous."

It therefore seems safe to give the distribution of this species at least as Fiji Islands and Funafuti.

11. Porites viridis Gardiner.

Plate 89, figures 1, 1*a*, 1*b*, specimen from Murray Island.

1898. *Porites viridis* Gardiner, Proc. Zool. Soc. London for 1898, p. 268, plate 24, figs. 1*b*, 2

1905. *Porites fidjiensis nonadecima* Bernard, Cat. Porites Indo-Pacific, p. 57, plate 4, figs. 2, 3, 4; plate 13, fig. 11.

The following are Bernard's introductory remarks on the specimens from the Fiji Islands and his general description:

"Under this heading I have grouped five specimens whose affinities have already been pointed out by Mr. Gardiner. They differ from one another in most striking ways, yet close analysis shows them all to be variations of one special type of modification.

"*General Description.*—The corallum may either be incrusting, with thin edges, but with the surface raised into solid rounded ridges, separated by deep, sharp, irregular valleys, or as solid hemispherical mounds with a marked tendency for the upper surface to be broken up into rounded hummocks, separated by narrow fissures or infoldings.

"The calices are conspicuous and funnel-shaped, with sharp wall-ridges which make them polygonal; when the ridges are absent the calices are round, mostly just under 2 mm. in diameter. The walls are a stout flaky reticulum which varies greatly in texture, and upon these variations depend the extraordinary differences of habit seen in the specimens, no two being alike. The wall-ridge is only slightly developed upon the convex surfaces, but in the valleys it forms the whole wall. Below the ridge the septa begin at once to appear as flakes sloping downwards into the fossa; deeper down they lengthen, and, according to their thickness and the depth of the calicle, form various more or less incomplete septal patterns.

"The polyps in life are a very bright dark green."

[1]Proc. Zool. Soc. London for 1898, p. 270, plate 24, figs. 1*e*, 4, 1898. [2]*Op. cit.*, p. 68.

The following is a brief description of the Murray Island specimens:

Corallum rises above an incrusting base and forms gibbosities, which are short, low, rounded lobes and flat-topped ridges; rather more lobate than in *P. mayeri*.
Calices about as in *P. mayeri*.

Wall membranous, elevated, and more or less zigzag where the reticulum is not developed; where the reticulum is developed it usually can be traced. The reticulum, although the radial structures are important in its composition, is secondarily thickened and becomes flaky in appearance. The development of flakes is by tangential and horizontal thickening, thereby contrasting with *P. mayeri*, in which the radial structures are more conspicuous.
The septa, pali, and columella of both species are similar in arrangement.

The difference between the two, therefore, consists in the greater development of the radial structures in the reticulum of *P. mayeri*, while in *P. viridis* there is a greater development of the tangential and horizontal structures, and there is in the latter a membranous wall, which may be zigzag. (See note at end of discussion of *P. mayeri*, page 197.)

Stations, Murray Islands.—Southeast reef, line I, 600 and 1,000 feet from shore.
Distribution.—Fiji Islands; Murray Island.

12. Porites densa, new species.

Plate 89, figures 2, *2a*, *2b*, specimen from Murray Island.

The following is a description of this species:

Corallum with incrusting base; edge shows younger growths over the older; upper surface irregularly rounded, but not thrown into gibbosities or rising into lobes or ridges.
Calices conspicuous; diameter measured between thecal summits, up to 2.5 mm. The fossæ are pits, sunk into a wide mural reticulum. Diameter of the pits 0.75 to 1 mm.; reticulum up to 1.5 mm. across; the width of the reticulum therefore exceeds the diameter of the calicular pits.

The mural trabeculæ usually project above the reticulum so as to form a traceable ridge; their ends are irregular in shape and size, but radially compressed and incompletely fused.
Septa usually 12, sometimes 11, in number, thick, considerable irregularity in arrangement, interseptal loculi narrow, irregular in size. Usually 2 lateral pairs, a solitary (dorsal) directive, and a ventral triplet may be recognized, but one member of a pair may be short, rendering the pair-fusion incomplete. Whether the short member of the pair is dorsal or ventral with reference to the long member seems inconstant. The short septum, however, is thick. There is irregularity in the condition of the triplet, but the lateral members are rarely fused by their inner ends to the directive.

The outer synapticular ring is strongly developed. It occurs somewhat below the upper edge of the mural trabeculæ and forms a coarse inner wall. Frequently an irregularly shaped tooth, granulate on the end, stands up on the septal margin at the inner edge of the ring; or a flattish, thick tooth may project inward, sloping upward at a relatively low angle. There is conspicuous irregularity in the septal teeth, but the persistent presence of certain teeth, which project inward in nearly horizontal planes or incline upward at low angles, is striking. Between the synapticular ring and the mural trabeculæ the septa are greatly thickened, with the result that the mural, synapticular, and outer septal structures form a relatively dense reticulum between adjacent calicular fossæ. Because of the subhorizontal teeth, the reticulum presents a flaky appearance.

Deeper down in the calice one or two subhorizontal teeth project inward on each septal margin. There are no definitely developed pali, but on the inner ends of some septa are irregularly shaped knots. The inner synapticular ring is irregular in development, rarely complete. Columellar tangle irregular in development, composed of thick, irregularly bent, fusing prolongations from the inner septal ends and some synapticulæ. Because of the irregularity in the length of the septa, the incompleteness of the inner synapticular ring, and the irregularity of the septal prolongations into the columellar tangle, the inner ends of interseptal loculi are correspondingly irregular.

Usually there is a columellar tubercle, represented by an axial knot rising above the columellar tangle, but there is no persistent axial trabecula terminating in a tubercle, as in

most species of the genus. Except on the structures mentioned, there is relatively little granulation of the skeletal surfaces.

Station, Murray Island.—Southeast reef, line I, 1,600 feet from shore; water 10 inches deep.

Distribution.—Murray Island.

13. Porites pukoensis Vaughan.

Plate 90, figs. 1, 1*a*, 1*b*, specimen from Fanning Island; figure 2, calices of a paratype from the Hawaiian Islands.

1907. *Porites pukoensis* Vaughan, U. S. Nat. Mus. Bull. 59, p. 195, plate 94, plate 95, figs. 1, 2.

In order to make a proper comparison with the specimen collected by Mr. C. Elschner at Fanning Island, it is necessary to quote my original description and notes on the suite of specimens from the Hawaiian Islands:

"Corallum forming thick, irregular, compressed or subterete, nodose columns, on which humps or stumpy protuberances may occur. The columns rise from a common base, and are more or less fused throughout their length, except the free projecting ends, or in some instances they are fused both above and below, leaving intermediate open spaces. Two views, natural size of the type specimen, showing the habitus and size of the corallum, are given on plates XCIV, XCV. There are three other specimens: The largest is of nearly the same size as the type, the columns distally diverge more, their ends are truncate, and some of them are more compressed. One of the other specimens is young, incrusting a branch of a species of *Porites* and sending up columns from 24 to 42 mm. in height, tapering to rounded or truncate ends. The fourth specimen is composed of several lobes, tapering to rounded ends, and a twisted, truncate plate, all rising from a common base. It shows no notable difference from the third specimen.

"Calices polygonal, excavated, rather deep, diameter from 1.25 to 1.5 mm.; separated by elevated, simple, perforate walls. Mural denticles rather tall, minutely frosted, about twice as many to a calice as there are septa.

"The septa usually begin a slight distance below the upper edge of the wall. Between a palus and the wall, there is usually a single septal trabecula, terminating above in a septal granule, usually not prominent, and slightly detached from the wall. Rough radial denticles may be present on both the mural and septal trabeculæ. There is an incomplete peripheral ring of synapticula, no distinct mural shelf. Septal faces frosted, often rather densely and coarsely; interseptal loculi not very wide, frequently tend to be decidedly narrow, and may appear closed.

"Pali tall, slender, more or less lath-like; the formula complete; joined by a complete ring of synapticula.

"Columella tall, a narrow lamella, joined by thick radii to the inner ends of the septal groups.

"*Locality.*—Pukoo, Molokai; two specimens collected by Dr. J. E. Duerden; 1 specimen, also collected by Doctor Duerden, the locality label has been lost, but it probably comes from the same locality; 1 specimen, received from Dr. W. T. Brigham.

* * * * * * *

"The calicular characters of *P. pukoensis* are practically identical with those of *P. compressa* forma *angustisepta*. As was remarked in discussing the latter form, it is not at all unlikely that they may be only different growth-forms of the same species. However, the specimens at my disposal for study do not show intergradation.

"*P. lobata* forma *parvicalyx* (p. 200) is also closely related. It forms thicker columns, and its calices are smaller. The walls of the two are similar, but usually they are taller in *P. lobata* forma *parvicalyx*. Neither of the extreme conditions was seen in the calices of *P. pukoensis*. The septal granules of the latter are not so tall and are not so far removed from the wall; the pali are constantly present and the columella tangle does not become an indefinite mesh-work.

"The three forms, *P. compressa* forma *angustisepta*, *P. pukoensis*, and *P. lobata* forma *parvicalyx* constitute a most interesting series. It may be that they all belong to the same species. Should they do so, they will show that the growth-form of corals is of only slight systematic importance."

A restudy of a paratype of the species, No. 22236, U. S. Nat. Mus., leads to a modification of the foregoing description. On some septa there are two intermediate denticles or granules between the palus and the wall. As the figure of the calices in my Hawaiian monograph lost so much in reproduction that it is not satisfactory, a new figure is here published (plate 90, fig. 2), and is placed alongside the figures of calices of the specimen from Fanning Island. It will be noted that in the calices of the latter, although there are usually two septal denticles outside the palus ring, sometimes there is only one. Here it may again be remarked that it is often difficult to decide whether a tooth on a poritid septum represents a trabecula or is only a trabecular process.[1]

The growth-form of the Fanning Island specimen is shown by plate 90, figure 1. The corallum consists of ascending, more or less clavate lobes, which are flattened on top.

Distribution.—Hawaiian Islands; Fanning Island (C. Elschner).

14. Porites lichen Dana.

Plate 90, figure 3, specimen from Cocos-Keeling Islands.

1846. *Porites lichen* Dana, U. S. Expl. Exped., Zooph., p. 567, plate 56, fig. 3.
1907. *Porites lichen* Vaughan, U. S. Nat. Mus. Bull. 59, p. 214, plate 90, figs. 2, 2*a*, 2*b*.

The only character in the Cocos-Keeling specimens which seems to need special consideration is the triplet. The usual condition is for the inner ends of the lateral members to reach the palar ring of synapticulæ, where occasionally a cross-bar or membrane may join them to the ventral directive and stand above the level of the columella tangle, but there is much irregularity in the septal grouping. The type of *P. lichen* was re-examined to ascertain the constancy with which the laterals of triplet fuse to the directive. In some instances the laterals do not fuse by their edges to the directive. There is much irregularity and frequently both directives can not be recognized with certainty. In some instances there appears to be no triplet, but a single septum represents it. The irregularity in septal arrangement is probably due to asexual reproduction frequently being by fission. The variation overlaps, so that the forms, in my opinion, represent one species.

Habitat, etc., Cocos-Keeling Islands.—Dr. F. Wood Jones states in his notes:

"Not uncommon on the barrier. The color of the coral is very constantly yellow with the exposed part of the zooid brick red. Found only as an incrusting layer."

Distribution.—Fiji Islands (Dana's type); Cocos-Keeling Islands.

15. Porites andrewsi, new species.

Plate 91, figures 1, 1*a*, 2, 2*a*, specimens from Murray Island. Also plate 14, figure 16, of Dr. Mayer's article.

1905. *Porites queenslandiæ duodecima* Bernard, Cat. Porites Indo-Pacific, p. 116, plate 19, fig. 6.

The following is a description of this species:

Corallum forming clumps of irregularly crooked, anastomosing branches, the summits of which are often divided into tufts of divergent branchlets. Height of corallum exceeds 115 mm. Diameter of branch low down 12.5 by 20 mm. Length of terminal branchlets up to 22 mm.; branchlets taper toward obtuse tips, 3.5 to 4 mm. in diameter; or have compressed, obtuse tips up to 5 by 12 mm. in diameter. Where a branchlet is subdividing the width may be as much as 20 mm. Depth of living tissue ranges up to 45 mm.

Calices shallow, small, usual diameter between thecal summits about 1.25 mm. Fossa about two-thirds the calicular diameter.

Mural summits indefinite, mural trabeculæ terminate in irregularly shaped, curly, flaky, frosted denticles which are incompletely fused.

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[1]For a discussion of the poritid septum see U. S. Nat. Mus. Bull. 59, pp. 169–216, especially pp. 169–170.

Septa thick, sides densely and coarsely granulate; interseptal loculi correspondingly narrow. A synapticular ring just within the wall, with a ring of rather ragged, tangentially compressed denticles above it. The wall, the outer synapticular ring, and the outer denticles by thickening may form a reticulum of flaky appearance. Just within this ring of denticles is a second ring which is between the outer one and the pali. The palar synapticular ring is weakly developed, notwithstaning the thick septa.

There are usually 6 stout, tall, densely granulate pali; one before each of the 4 lateral pairs, and one on each of the directives, but the one on the solitary directive frequently corresponds to the intermediate denticles of the other septa. Although the laterals of the triplet usually fuse by their inner ends to the included directive, the intermediate denticles may be so prominent on each member of the group as to simulate pali while the morphologic palus is small and pressed against the columellar tubercle. In some calices pali appear before the laterals of the triplet, the one on the directive apparently being suppressed. One of the striking characters is the great development of the intermediate denticles and the tendency for them to become confused with the pali.

Columella a conspicuous, granulated style, slightly less stout than the pali and usually not so tall, but often equaling or nearly equaling them in height; joined to the septa by a variable number of radii; five is a frequent number.

Stations at Murray Island.—Southeast reef, line I, as follows:

400 feet from shore; depth of water, 4.5 to 5 inches.
600 feet from shore; depth of water, 15 inches; bottom mud and sand.
650 feet from shore; depth of water, 10 inches; bottom sandy.
800 feet from shore; depth of water, 11 inches; bottom hard, rocky.
1,200 feet from shore; depth of water, 9 inches; bottom rocky.

The foregoing description is based on a broken colony from 400 feet from shore, which in the character of its branches differs considerably from one specimen from 600 feet from shore and those farther out on the reef flat. The branches are more crooked, more interfused, and the depth of the living tissue is less. These characters are such as would result from an unfavorable environment. The following are notes on the different specimens.

600 feet from shore, 3 specimens: (*a*) a good colony; branches interfusing except near the tips, free as much as 17 mm.; depth of living tissue, as much as 67 mm.; in places an elevated mural thread may be traced between the calices; surface low down on the branches appears velvety, because of the great development of mural and septal denticles, in these areas the reticulum is greatly developed and flaky; calicular characters similar in scheme to those given in the detailed description. (*b*) 3 fragments, 2 from one colony; branches not interfused, otherwise no important difference from (*a*).

650 feet from shore, 1 specimen; not notably different from (*b*) of the preceding note.

800 feet from shore, 2 good specimens: both have the branches and branchlets free. (*a*) Closely similar to specimen on which the detailed description is based, except that the branches are not so crooked and do not interfuse. (*b*) Similar to (*a*), except that the branch terminals may be compressed and wide (plate 91, figs. 1, 1*a*), width up to 24 mm. and about 5 mm. thick.

1,200 feet from shore, 1 good colony (plate 91, figs. 2, 2*a*), branches free, rather divergent; most of the surface velvety, with the appearance of bloom on it, but two branchlets are similar to those of the other specimens.

The variation consists mostly in the form of the colony, whether the branches are or are not interfused, and whether crooked or rather straight; and in the degree of the development of the flaky reticulum and its associated denticles. It is on the latter that the velvety appearance of the surface of the older parts of the corallum depends. The columellar style may be only a small point. Therefore, the detailed description needs only slight modification to comprehend the specific characters, which are the growth-form, and the mural and calicular characters.

This coral is the one designated by Bernard *Porites Great Barrier Reef* (42)12, and is probably also his *Porites Great Barrier Reef* (42)42.

Although it is to be expected that either this or closely related species occur generally in the tropical Pacific, I have seen no named species to which it can positively be referred. It is distinct from any of Dana's species represented by types in the U. S. National Museum, but is close to *P. cylindrica*, which is the next species to be described. Dana's type of *P. levis* is not in the National Museum. Bernard identifies his *Porites Fiji Islands* (24)1 with *P. levis* (*op. cit.*, p. 43, plate 2, fig. 2). This is almost certainly what I am here calling *P. andrewsi*. The same species is represented by Bernard's *Porites Tonga Islands* (10)8 and (10)9. Dana's figure of the calices of *P. levis* (plate 54, fig. 5*c*) represents septal granules different from those of *P. andrewsi*, *i. e.*, there are not the usual two clear-cut rings of granules between the pali and the thecal summits; and the growth-form of *P. levis* is different. It is probable that Bernard is correct, but unless it is more positively shown that the two actually intergrade, I prefer to consider *P. andrewsi* as distinct from *P. levis*.

Distribution.—Great Barrier Reef; Fiji Islands; Tonga Islands.

16. Porites cylindrica Dana.

Plate 92, figures 3, 3*a*, Dana's type of the species.

1846. *Porites cylindrica* Dana, U. S. Exp. Exped., Zooph., p. 559, plate 54, fig. 4.

This species is so very close to *P. andrewsi* that for some time I was undecided as to whether they should be separated. The growth-form is similar enough for them to belong to the same species, and the fundamental skeletal plan is the same in both, but the septal granules in the two forms are constantly different according to the specimens available for study. They are smaller in *P. cylindrica*, less regularly developed, and not arranged in conspicuous rings separated by circular depressions as in *P. andrewsi*. However, it does not appear improbable that *P. levis*, *P. cylindrica*, and *P. andrewsi* may all belong to the same species.

Type: No. 708, U. S. Nat. Mus.

Locality.—Fiji Islands?

17. Porites nigrescens Dana.

Plate 91, figures 3, 3*a*, Dana's type of the species; plate 92, figures 1, 1*a*, 1*b*, specimen from Cocos-Keeling Islands; figures 2, 2*a*, probably a variant of the species, from Cocos-Keeling Islands.

1846. *Porites nigrescens* Dana, U. S. Expl. Exped., Zooph., p. 557, plate 54, figs. 1, 1*a*, 1*b*.
1905. *Porites fidjiensis octava* Bernard, Cat. Porites Indo-Pacific, p. 51.

Dana's type is in the U. S. National Museum, No. 691. As good descriptions of the form have been given by both Dana and Bernard, that feature of the corallum need not be treated here. The following is a description of other features of Dana's type:

The intercorallite walls are wide and flaky, usually without a well-defined wall-ridge, which, when present, is represented by a slightly elevated broken row of curly flakes. The calicular cavities are subcircular in outline and are slightly sunken below the flaky reticulum. Distance between thecal summits about 2 mm.; diameter of calicular openings about 1 mm.

The septa are thick, triangular in horizontal outline, outer ends wide, flaky, with a curled denticle near the wall; sides granulate; interseptal loculi narrow; number 12, formula complete, members of triplet ending separately. Typically 8 palar knots, those before the lateral pairs somewhat the larger. Palar ring of synapticulæ irregularly developed.

Columellar tubercle a small, twisted knot. Columellar tangle irregularly developed, as the ring of palar synapticulæ is not complete.

In the specimens from Cocos-Keeling Island this species is represented by pieces of three colonies. Those from two colonies differ from the type principally by the branches being more terete in cross-section (see plate 92, figs. 1, 1*a*, 1*b*), not anastomosing, and by delicate, curly, lace-like tracery along the mural summits. The latter difference may be due to the state of preservation of the specimens.

The other specimen (see plate 92, figs. 2, 2*a*) has more compressed branches and the calices, especially on one side, are more excavated. On both kinds of corallum near the base of the living tissue the calices are superficial; the columellar tubercle, 8 pali, and the septal denticles are distinct; and an echinulate-striate reticulum may be developed between the calices. It seems to me that the *Porites* described by Bernard from Cocos-Keeling (*op. cit.*, p. 196, plate 30, fig. 1) may belong to this species.

Habitat, etc., Cocos-Keeling Islands.—Dr. Wood Jones contributes the following notes:

"Fragments from the deeper portions of the lagoon. Not very abundant. In the inlets to the lagoon all sorts of debased branching and amorphous forms are to be found. Its color is grayish, sometimes with a greenish tinge. When dead it turns black. There is about this coral a peculiar smooth sliminess which is very distinct. It becomes extremely moist and sticky when dead and it stinks horribly not only when dead but even when exposed to sun and air by low tides."

Distribution.—From Cocos-Keeling to Fiji Islands.

Subclass ALCYONARIA Milne Edwards and Haime.

Family TUBIPORIDÆ Milne Edwards and Haime.

Genus TUBIPORA Linnæus.

Tubipora musica Linnæus.

1857. *Tubipora musica* Milne Edwards and Haime, Hist. nat. Corall., vol. 1, p. 132.

I am referring a series of specimens, collected by Dr. Mayer, to this species because the usual diameter of the corallites is 1.5 mm. The number to 1 centimeter is 5 to 6, rarely 4. The species may be *T. purpurea*, which has corallites nearly 2 mm. in diameter.

Obtained from stations at Murray Island, southeast reef, line I, 400, 600, 800, 1,000, and 1,600 feet from shore.

Class HYDROZOA.

Order HYDROCORALLINÆ Moseley.[1]

Family MILLEPORIDÆ L. Agassiz.

Genus MILLEPORA Linnaeus.

Hickson may be correct in his conclusion, which he expressed as follows:

"It appears to me that these investigations present very strong reasons for believing that there is only one species of *Millepora*. That one species must, on the ground of priority, be called *Millepora alcicornis*."[2]

But it is at least convenient, if not systematically sound, to recognize by distinctive names the different aspects presented by colonies. In the names here applied I have followed Dana and Klunzinger, without any attempt to go farther into questions of synonymy.

Millepora dichotoma Forskål.

Plate 93, figure 1, specimen from Cocos-Keeling Islands.

1879. *Millepora dichotoma* Klunzinger, Korall. Roth. Meer., pt. 3, p. 86.
1910. *Millepora* (of the type named *alcicornis*) Wood Jones, Coral and Atolls, p. 103, text-fig. 35.

The following are Dr. Wood Jones's notes:

"The characteristics of this form are (1) its color is almost always yellow, with the apices of the branches white, (2) when dead it bleaches pure white, (3) its stings are very severe, (4) it lives on the landward margin of the barrier."

[1]Although these are not corals, notes on them are included because of their importance as reef-builders.
[2]Proc. Zool. Soc. London for 1898, p. 256, 1898.

Millepora platyphylla Ehrenberg.

Plate 93, figure 2, specimen from Cocos-Keeling Islands.

1879. *Millepora platyphylla* Klunzinger, Korall. Roth. Meer., pt. 3, p. 84.
1910. *Millepora* (of the type named *complanata*) F. Wood Jones, Coral and Atolls, p. 102, text-fig. 34.

Dr. Wood Jones has made the following notes on this form:

"Color varies from brown to yellow or greenish yellow, it is lighter and brighter when growing luxuriantly; distal margin of the plate palest sulphur yellow or nearly white. Some color is retained in the dead specimens. Lives most luxuriantly on the seaward edge of the barrier, where it is very abundant. The plates spring from an irregular, incrusting base, the first being always opposed to the line of waves and currents. Other plates are added radially. The colonies attain a thickness of 4 to 5 feet in diameter and 3 to 4 feet high."

Irregular, incrusting, small masses of *Millepora*, which grow on the most exposed parts of the barrier, are probably referable to this form.

Millepora truncata Dana.

Plate 93, figures 3, 3*a*, 3*b*, specimen from Fanning Island.

1846. *Millepora platyphylla, β truncata* Dana, U. S. Expl. Exped., Zooph., p. 548, plate 53, fig. 2.

Mr. Carl Elschner obtained specimens of this form of *Millepora* at Fanning Island. It has gastropores about 0.3 mm. in diameter; dactylopores much smaller, but recognizable with the naked eye. It is close to the form to which Dana applied the name *incrassata*.

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EXPLANATION OF PLATES.

Plate 20.

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Figs. 1, 1*a*, 1*b*, 1*c*, 2, 2*a*. *Seriatopora hystrix* Dana. Fig. 1, general view of colony from Murray Island, half natural; figs. 1*a*–1*c*, three branch terminals, each ×3 (upper lips to calices are usually more obvious). Fig. 2, part of Dana's type of the species, No. 346, U. S. Nat. Mus., natural size; fig. 2*a*, branch terminal of the type, ×3 73

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Figs. 1, 2, 2*a*. *Pocillopora eydouxi* Milne Edwards and Haime. Fig. 1, view, ×1/2, of a specimen from Murray Island. Figs. 2, 2*a*, specimen from Cocos-Keeling Islands; fig. 2, view of side, natural size; fig. 2*a*, calices, ×8 79

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PLATE 44.

PLATE 45.

PLATE 46.

PLATE 47.

PLATE 48.

PLATE 49.—*Mussa sinuosa* (Lamarck).

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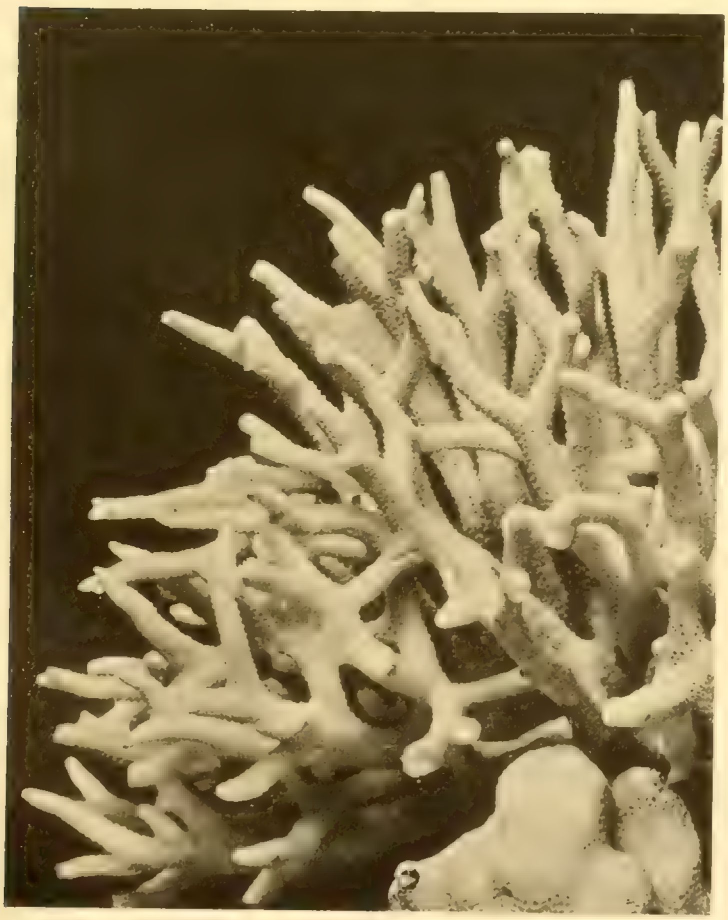
1 ×½

2a ×3

3

1a ×3

4



2

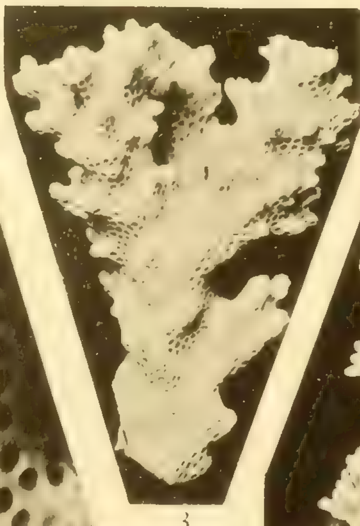
1b ×3

1c ×3

FIGS. 1, 1*a*, 1*b*, 1*c*, 2, 2*a*. *Seriatopora hystrix* Dana. FIGS. 3, 4. *Seriatopora angulata* Klz.

1

2



3

1a ×5

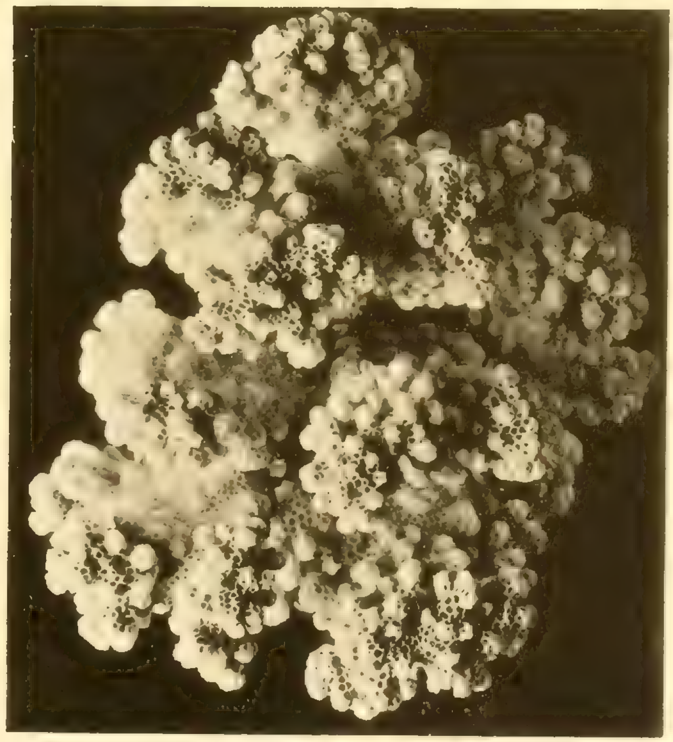
3 ×2/3

Figs. 1, 1*a*. *Pocillopora bulbosa* Ehr. Figs. 2, 3, 3*a*. *Pocillopora damicornis* (Pallas).

1

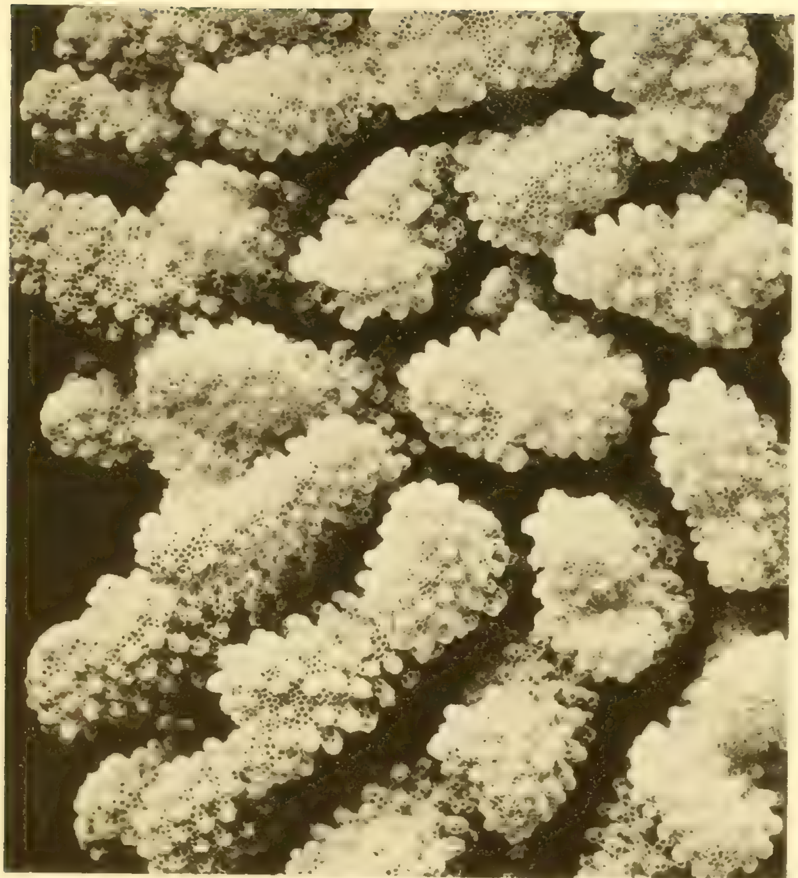
2

3



1a

FIGS. 1, 1*a*, 2. *Pocillopora danæ* Verrill. FIG. 3. *Pocillopora woodjonesi*, new species.



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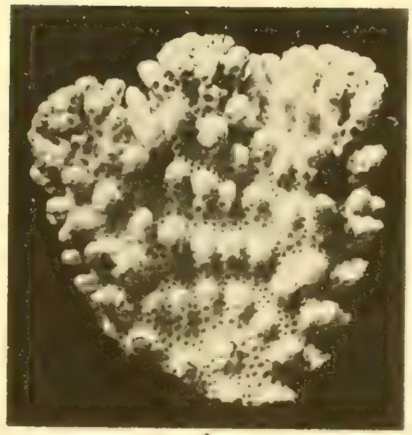

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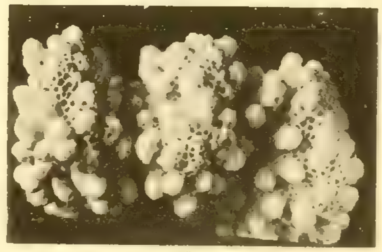
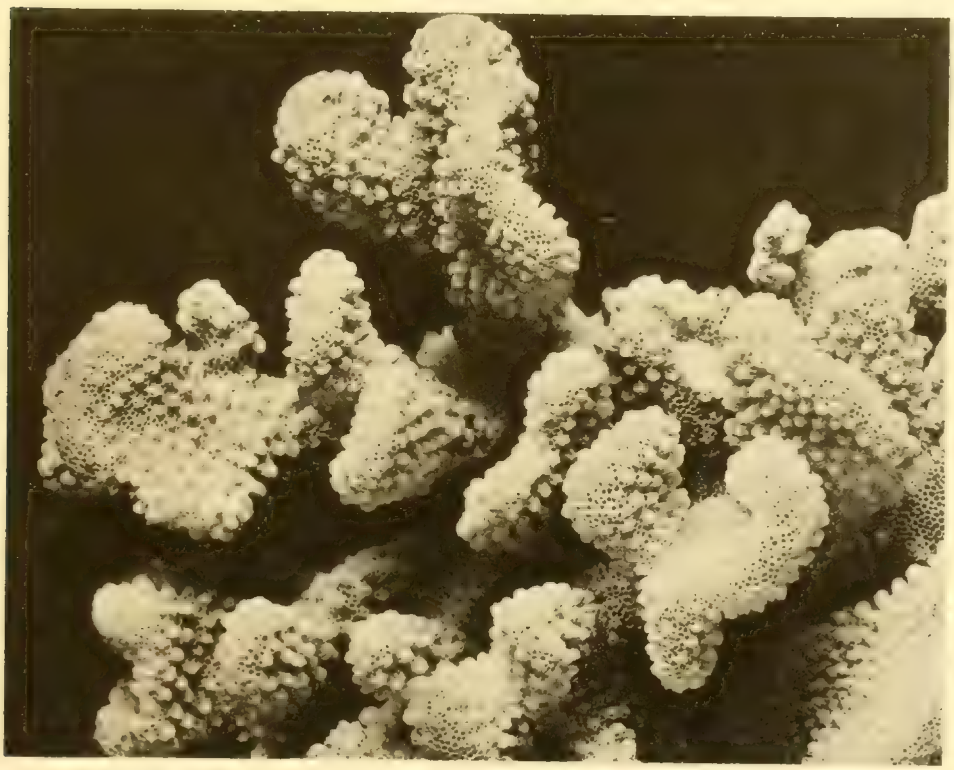


2a



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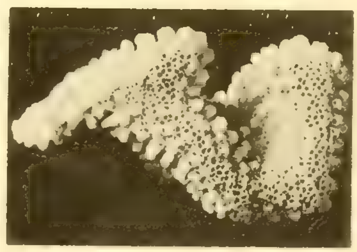

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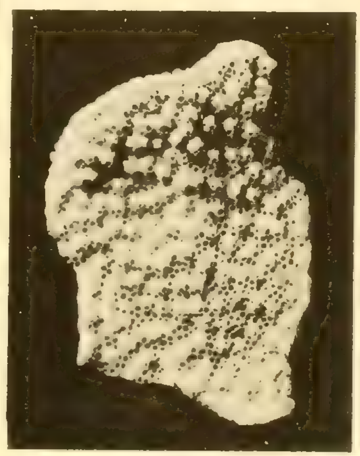
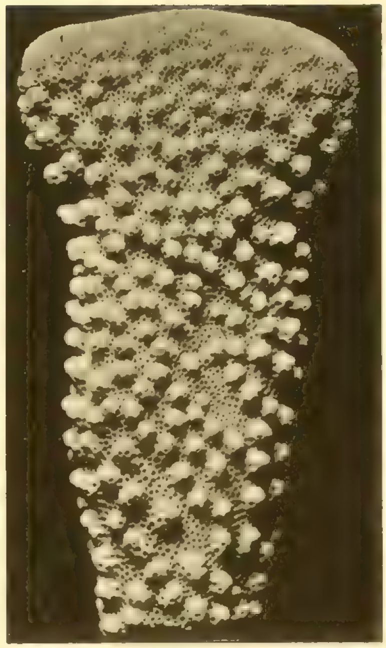


4a

FIGS. 1, 2, 2*a*. *Pocillopora verrucosa* (Ell. and Sol.). FIGS. 3, 4, 4*a*. *Pocillopora elegans* Dana.

1 ×½



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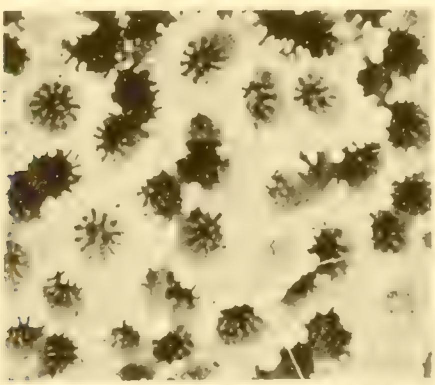
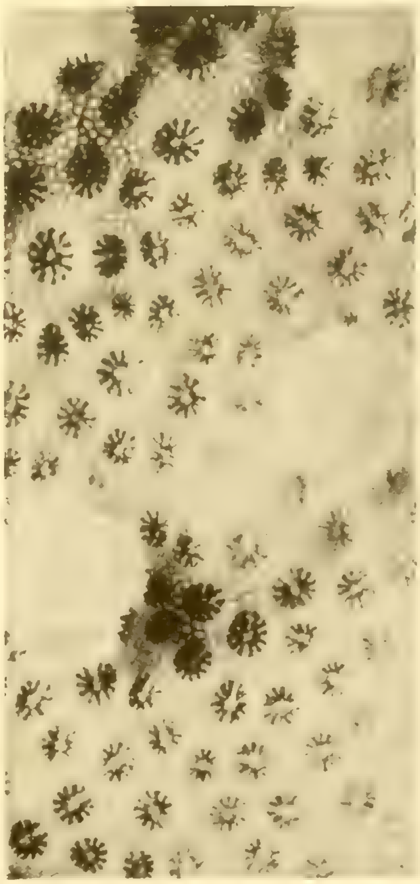
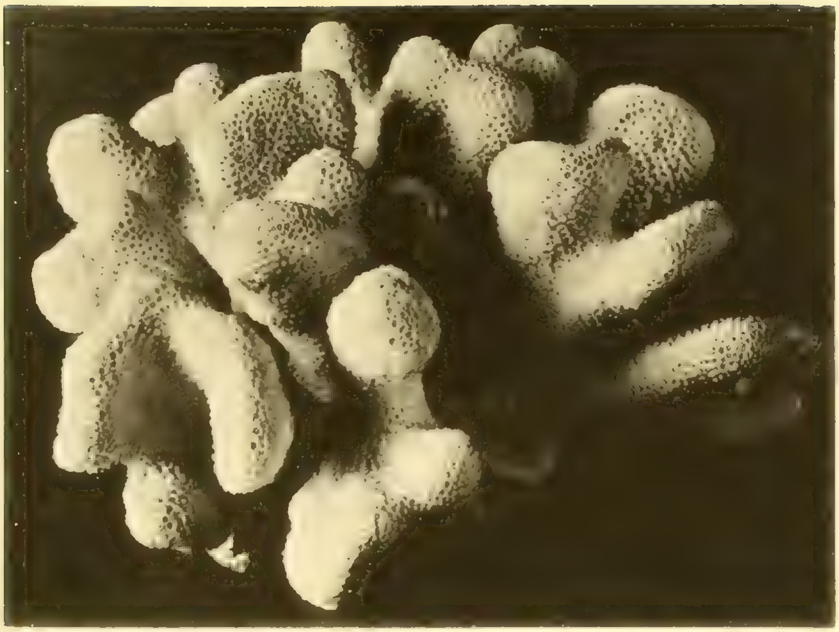


3 ×8

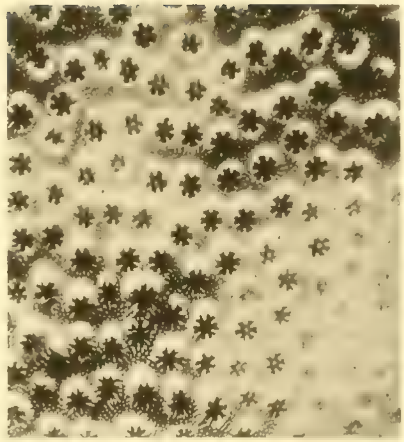


2a ×8

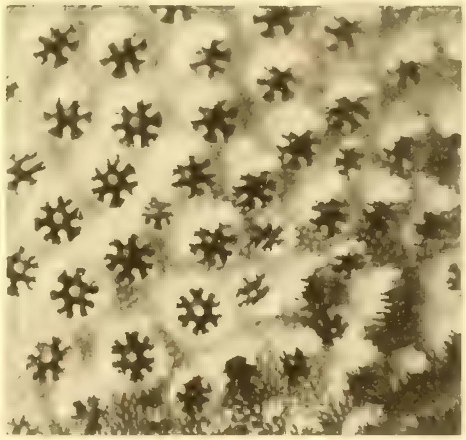
FIGS. 1, 2, 2*a*. *Pocillopora eydouxi* M. Edw. & H. FIG. 3. *Pocillopora woodjonesi*, new species.



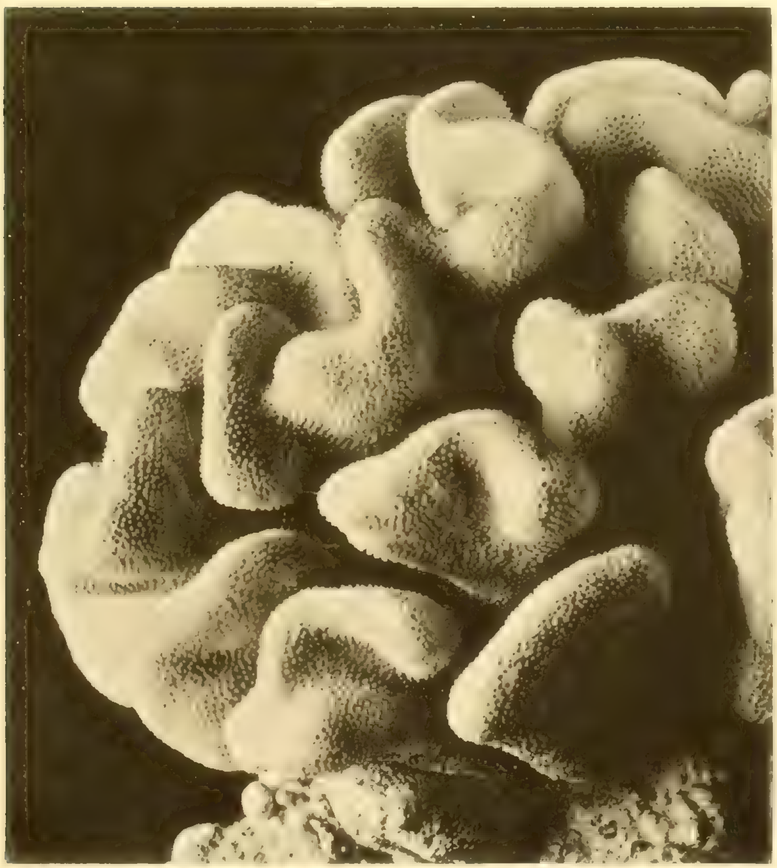
1



1a ×4



2b [illegible]



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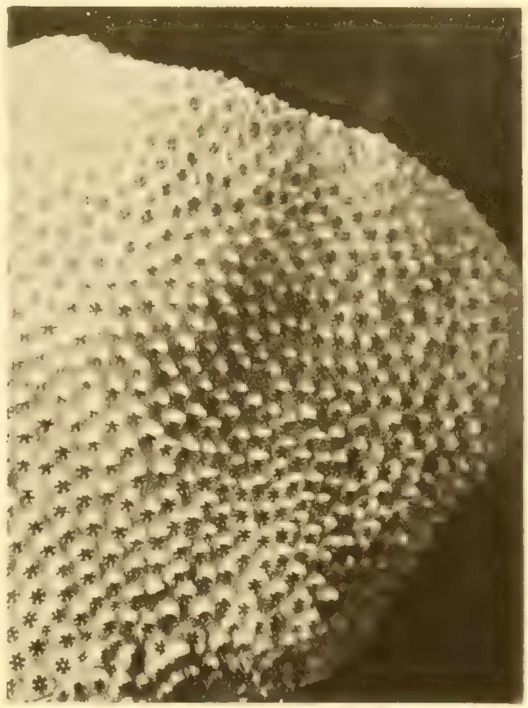
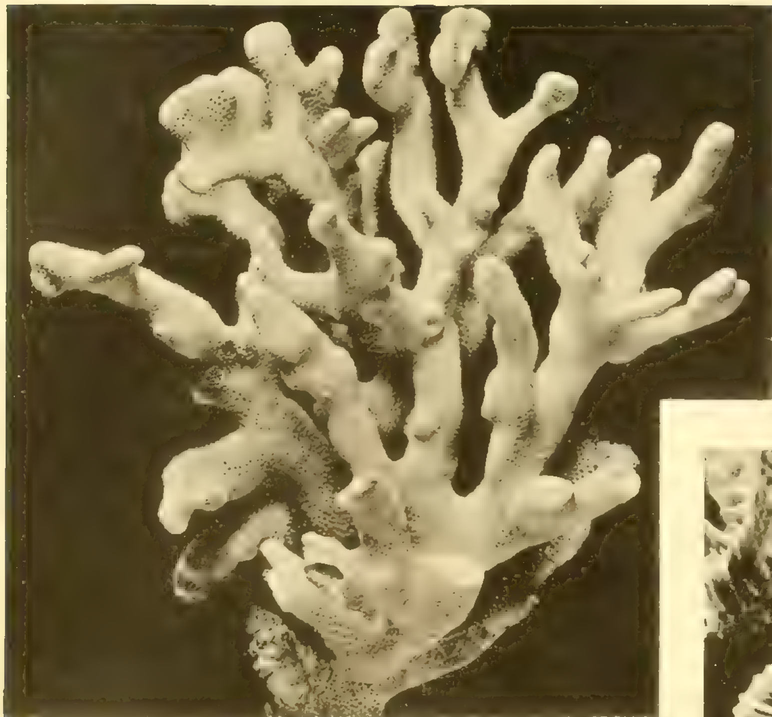
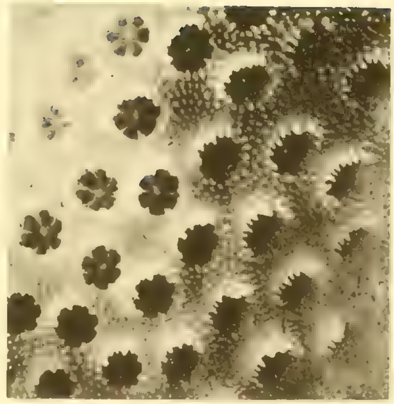


2a ×3

Stylophora mordax Dana.



1 ×½



1a ×8

3a ×2

2

3

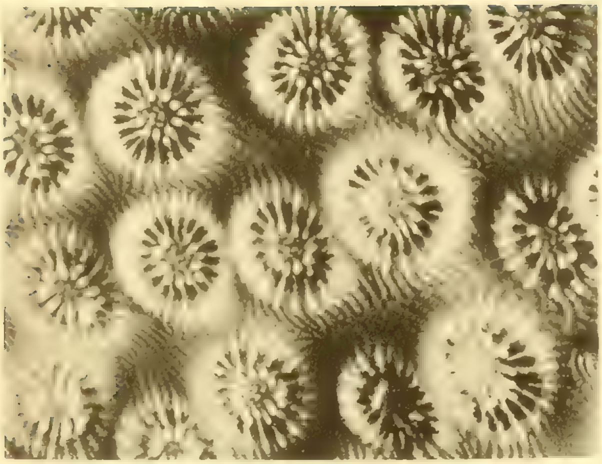
FIGS. 1, 1*a*. *Stylophora pistillata* (Esper). FIGS. 2, 3, 3*a*. *Euphyllia glabrescens* (Cham. and Eysenh.).

1

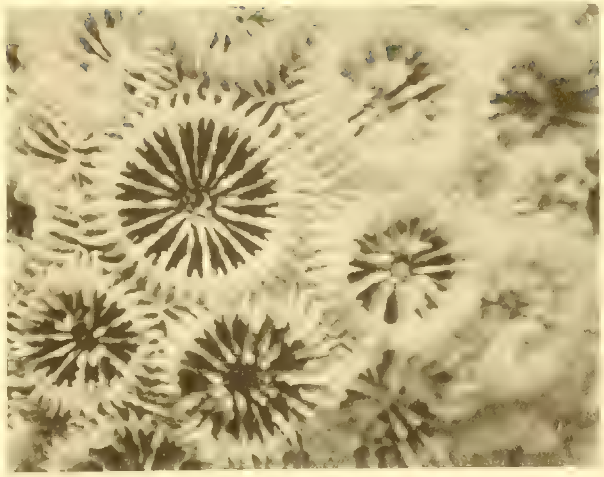
1[a]

2

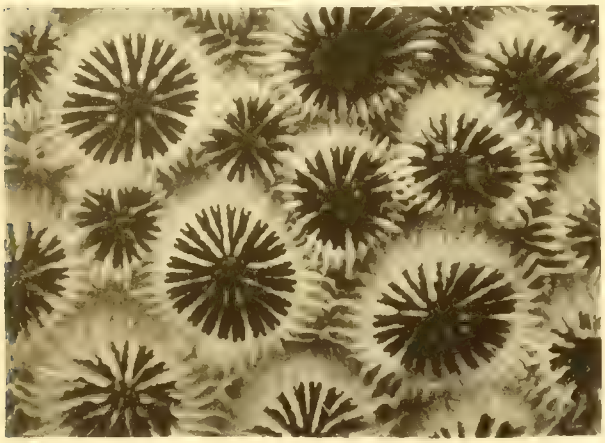
Euphyllia fimbriata (Spengler).



1 ×4

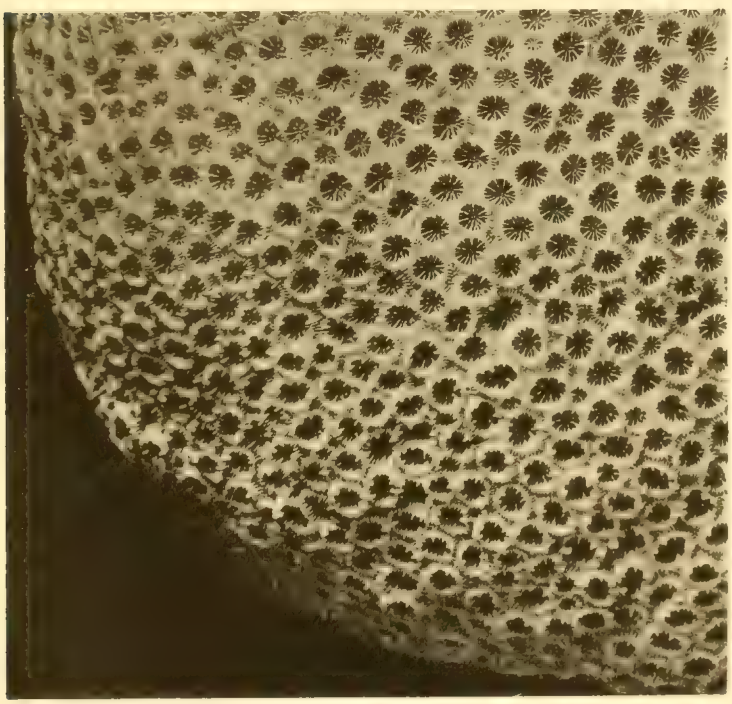


2 ×4



3 ×4

4[a] ×4

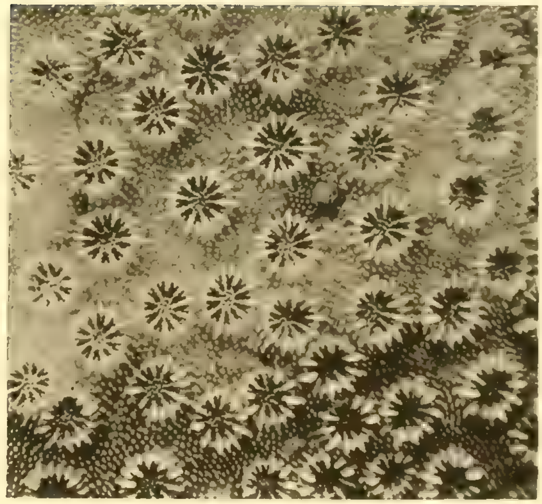


4

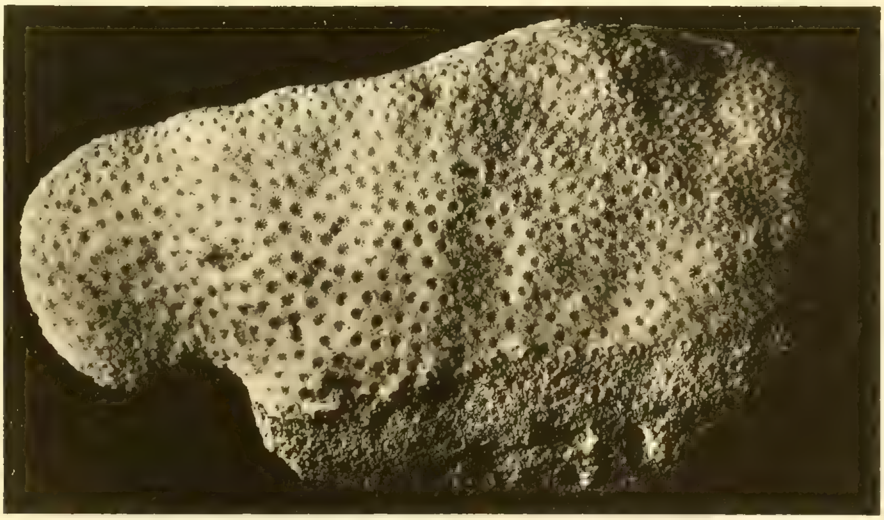
5 ×4

Fig. 1. *Orbicella versipora* (Lam.). Figs. 2, 3, 4, 4*a*, 5. *Orbicella curta* Dana.

1



1a ×4



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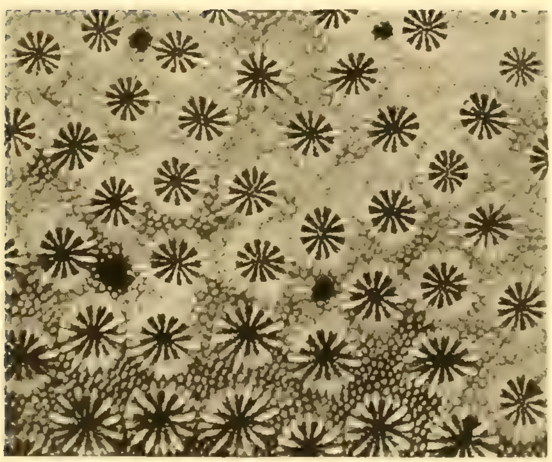
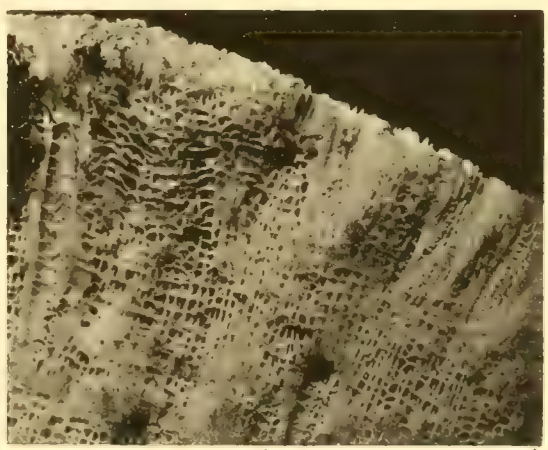
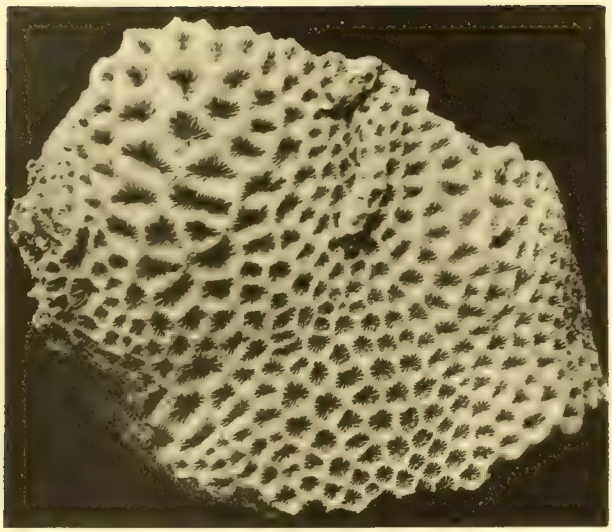


2a ×4

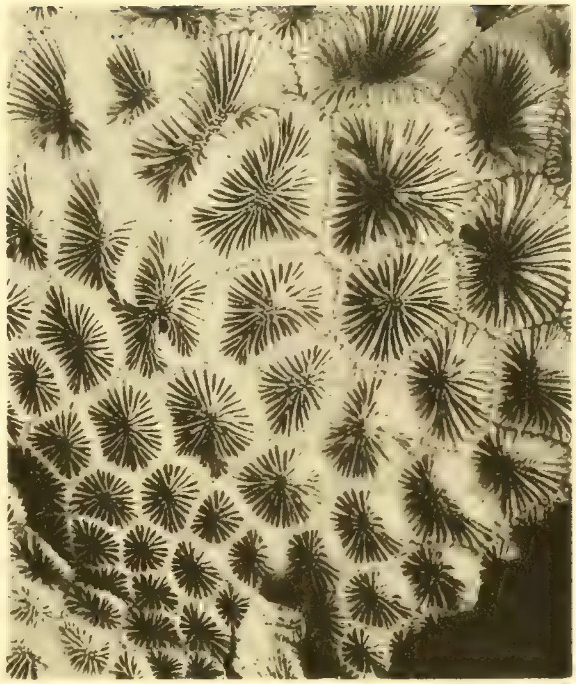


2b ×4

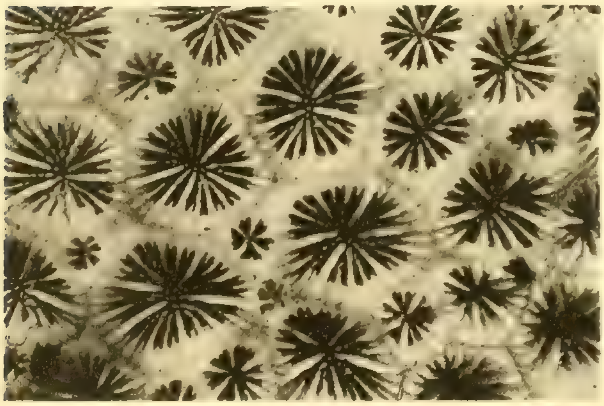
FIGS. 1, 1*a*. *Cyphastrea microphthalma* (Lam.). FIGS. 2, 2*a*, 2*b*. *Cyphastrea serailia* (Forsk.).



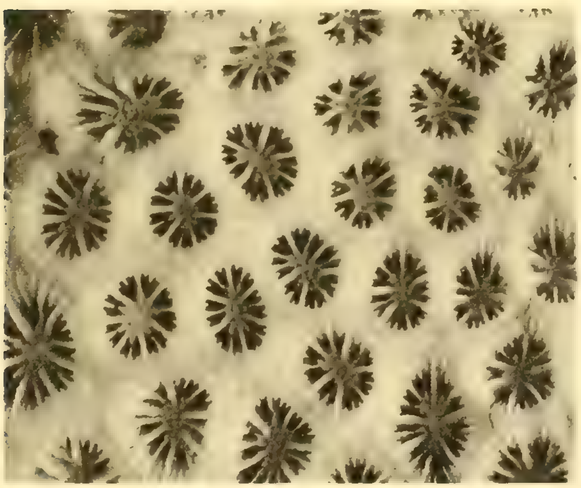
1



1a × 4



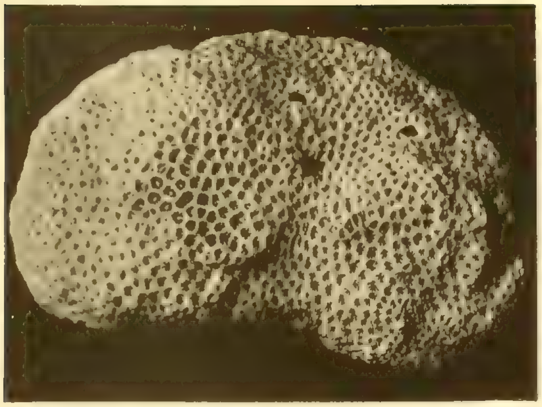
2 × 4



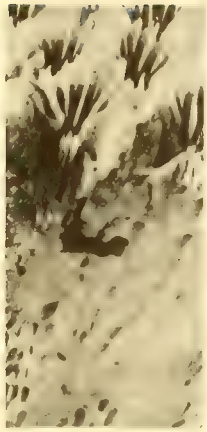
3 × 4

3a × 4

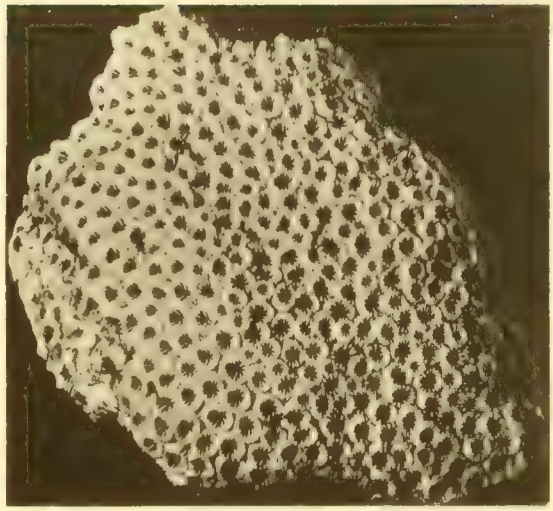
Leptastrea purpurea (Dana).



1 ×½



2b ×4



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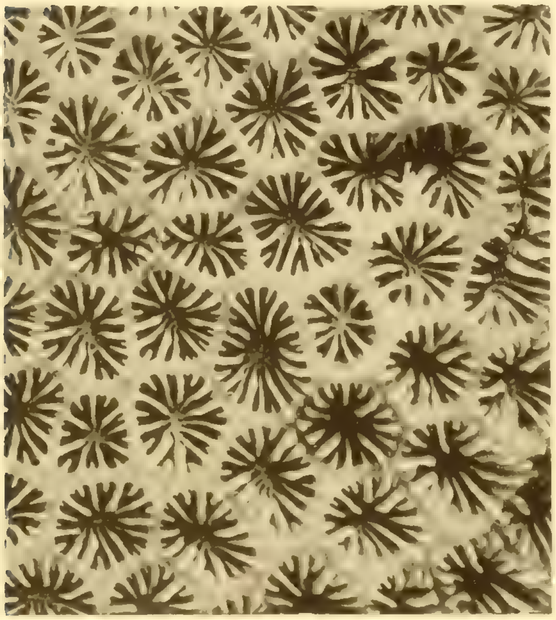
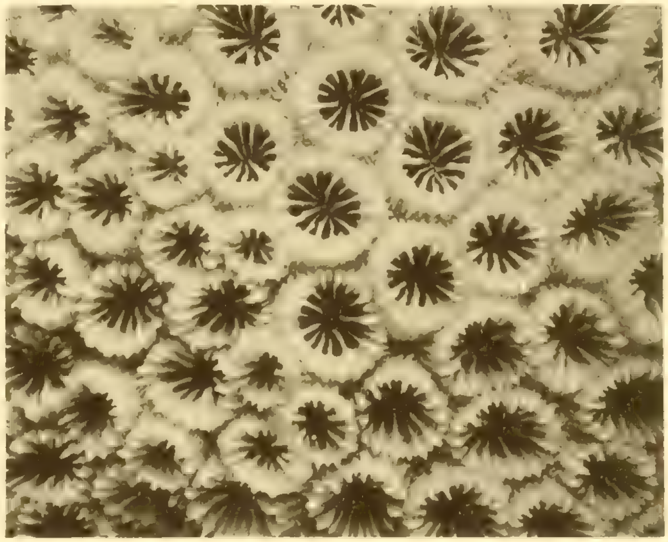
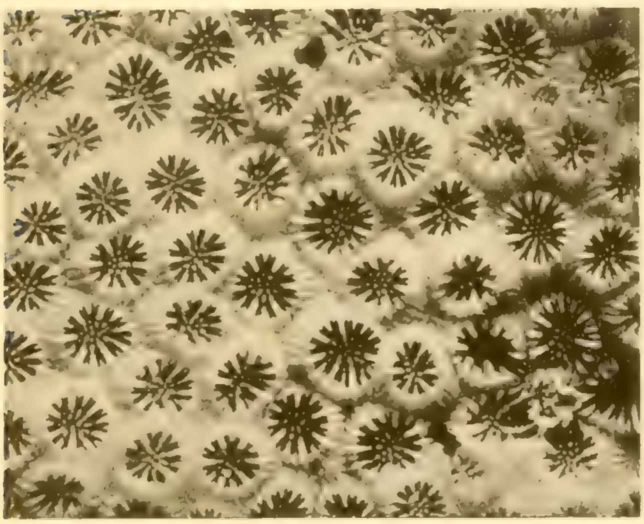


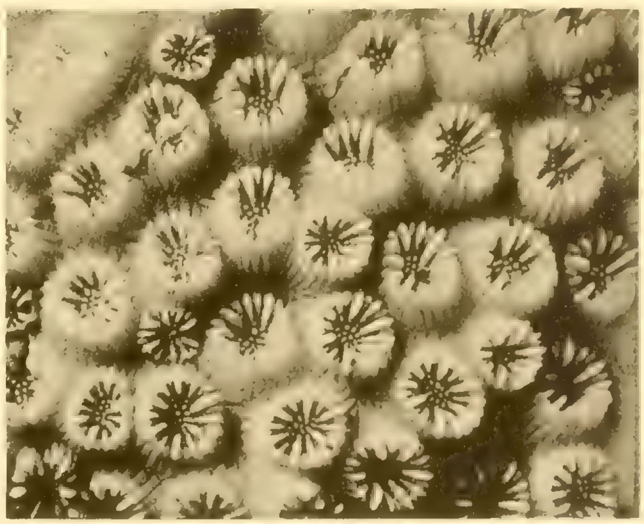
1a ×4



2a ×4

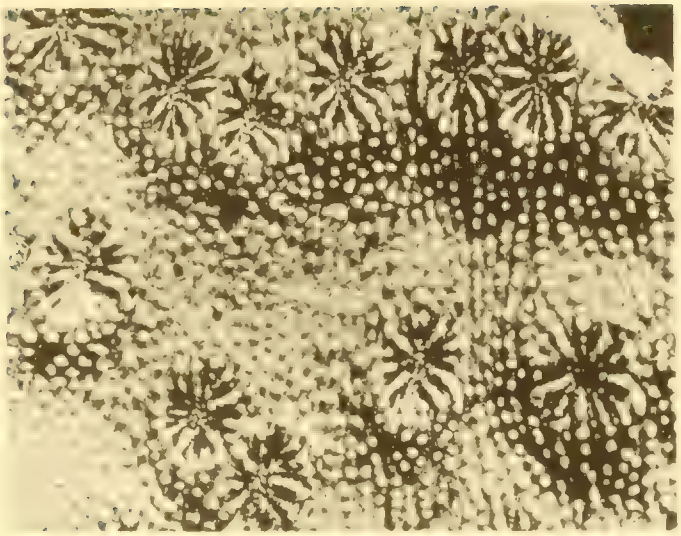


3 ×4

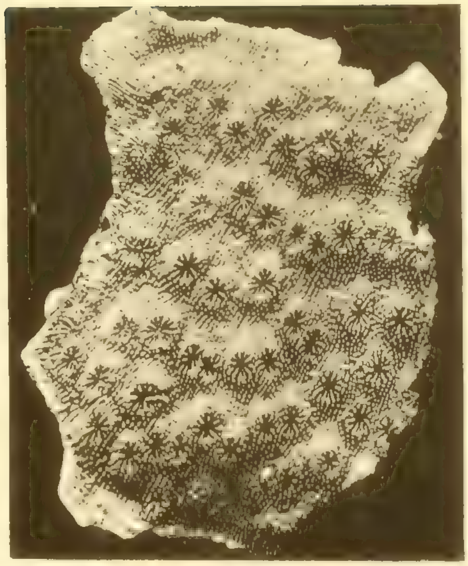


4 ×4

FIGS. 1, 1*a*. *Leptastrea transversa* Klz. FIGS. 2, 2*a*, 2*b*. *Leptastrea immersa* Klz.
FIGS. 3, 4. *Leptastrea bottae* (M. Edw. and H.).



1ª ×4



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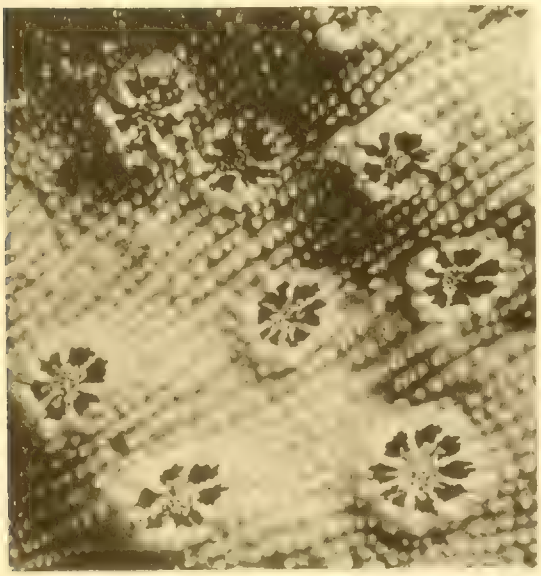
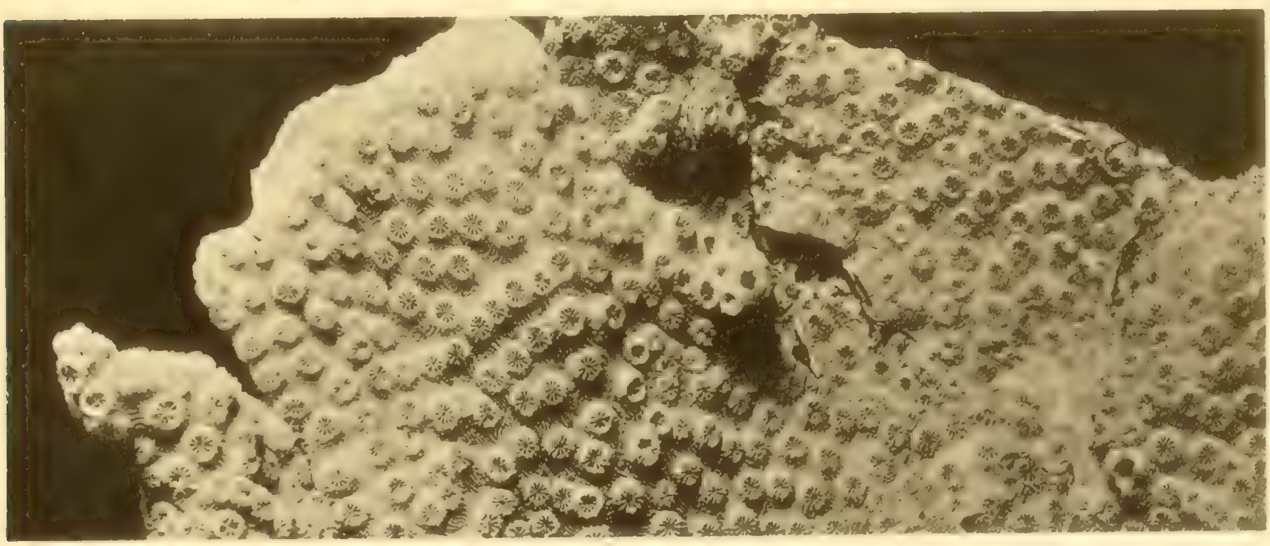


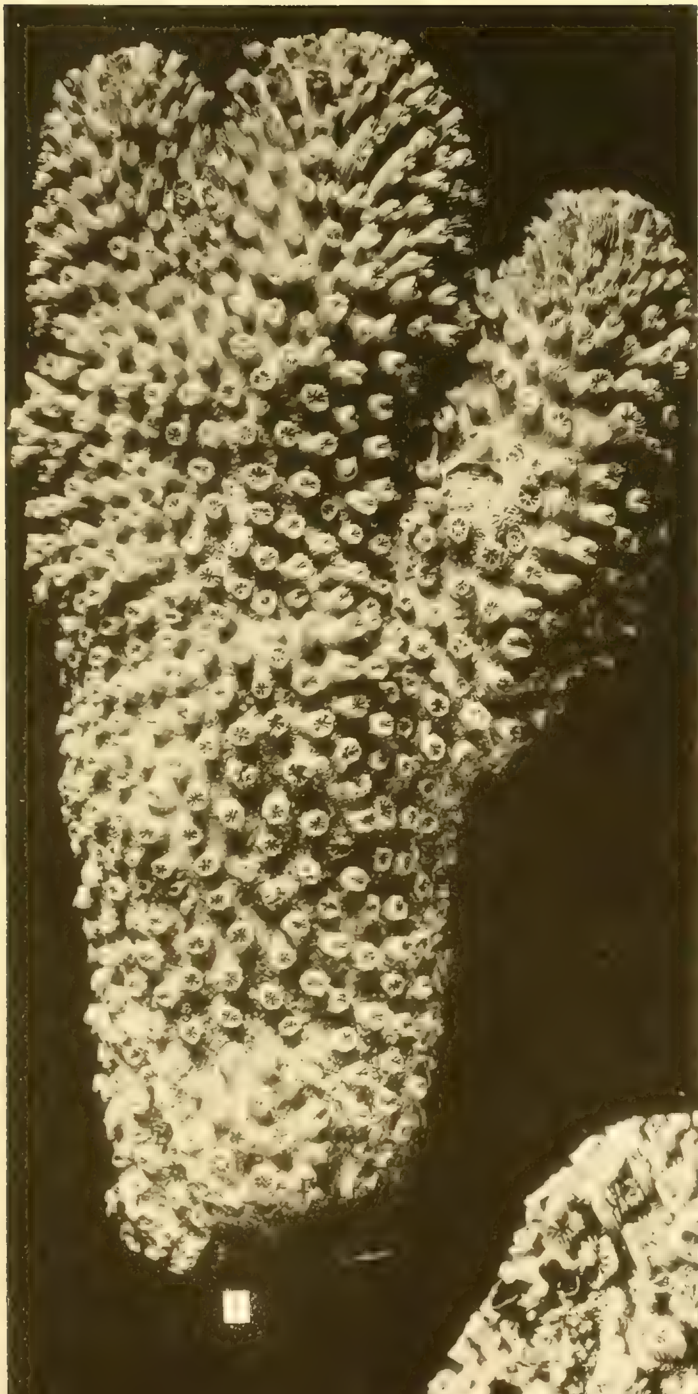
2ª ×4

2



3

Echinopora lamellosa (Esper).



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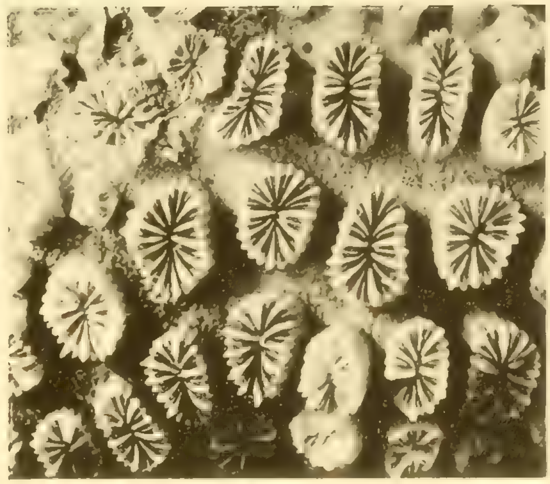
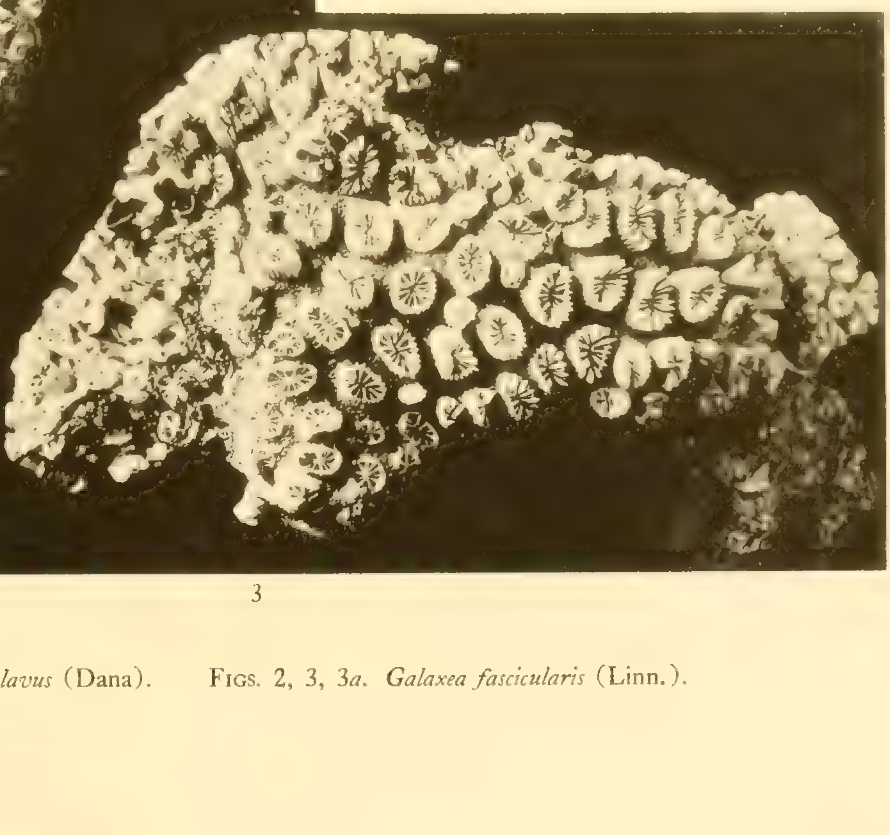
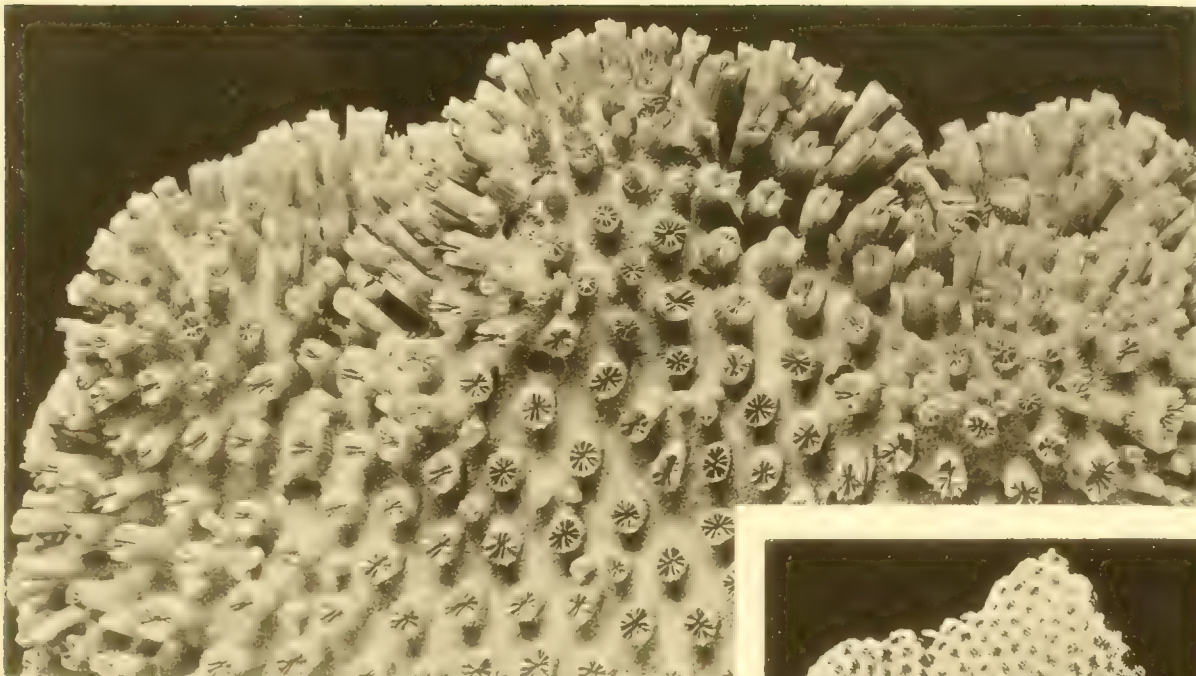


3a ×2

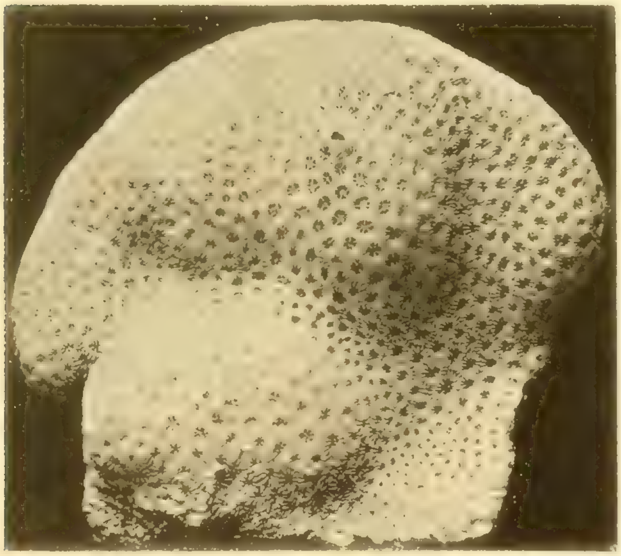


3

FIG. 1. *Galaxea clavus* (Dana). FIGS. 2, 3, 3*a*. *Galaxea fascicularis* (Linn.).



1



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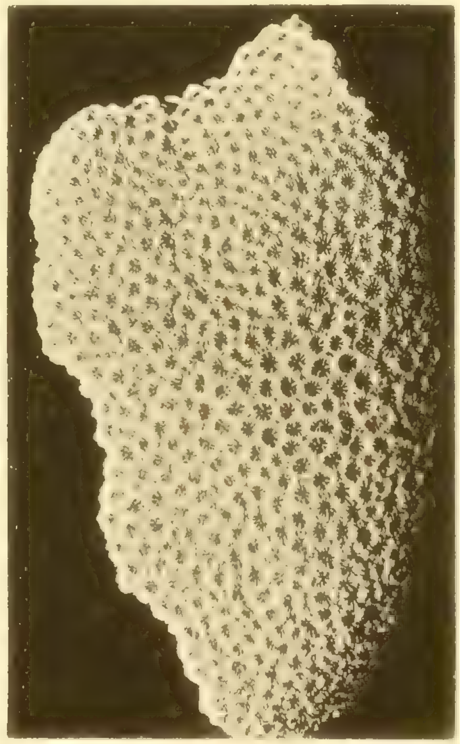

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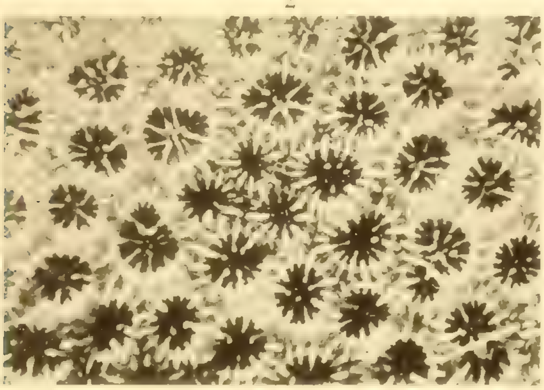
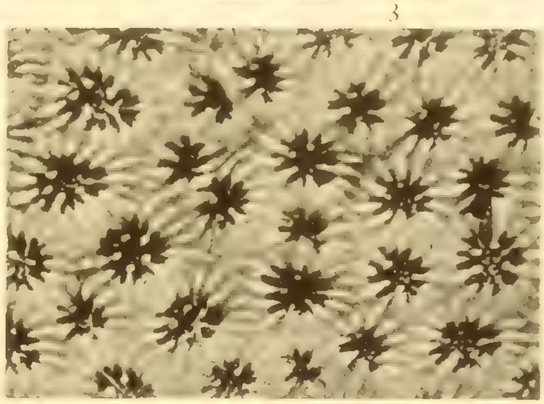
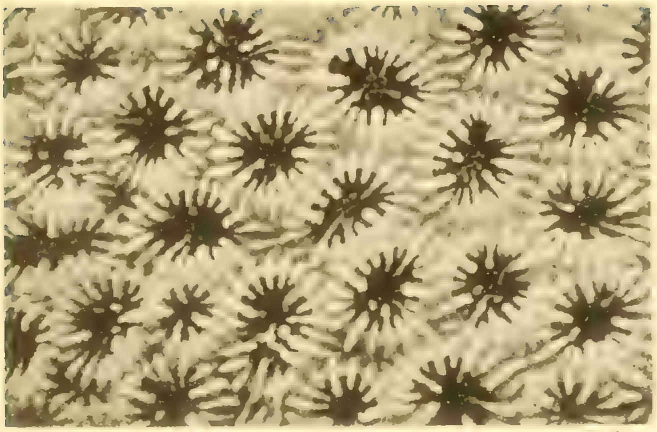


2a ×4

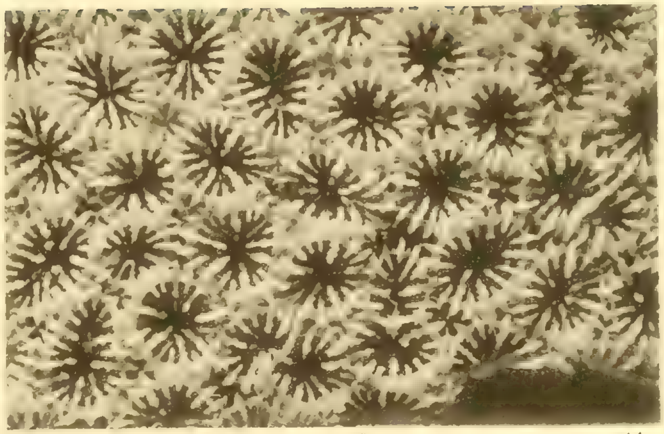


2b ×4

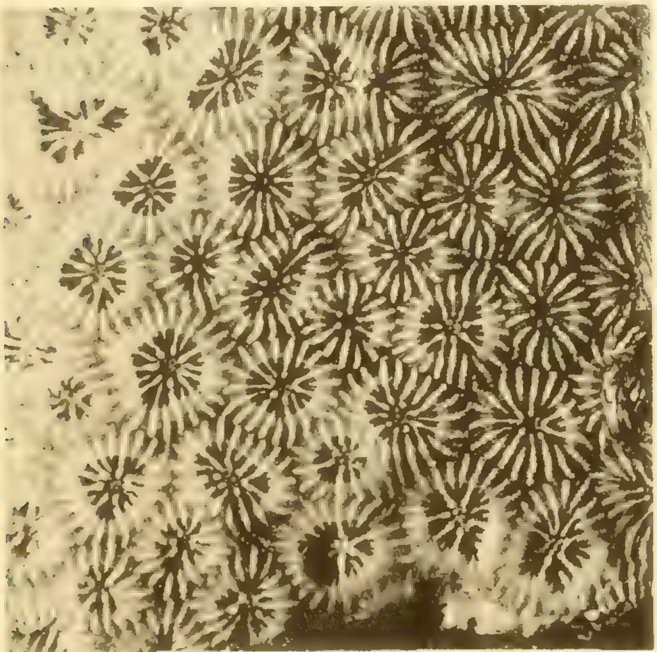
FIG. 1. *Galaxea fascicularis* (Linn.). FIGS. 2, 2*a*, 2*b*, 3. *Favia stelligera* (Dana).



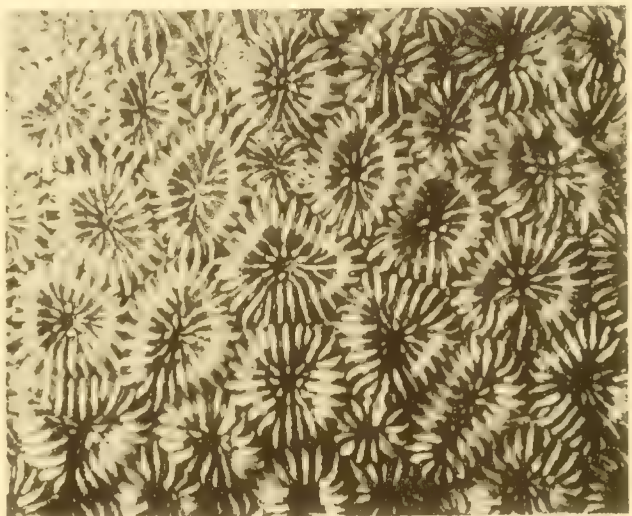
1 ×4



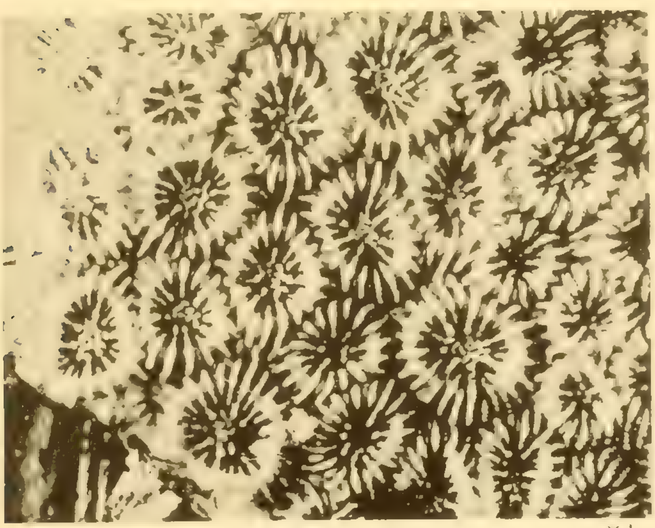
1a ×4



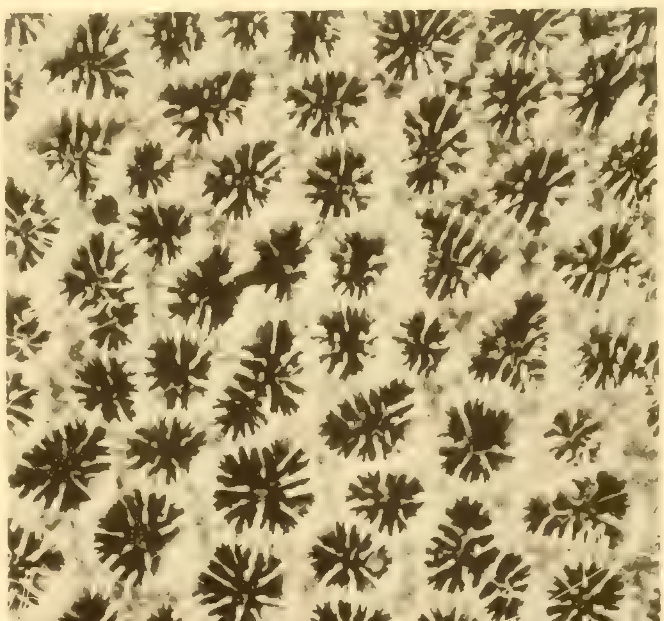
2 ×4



2a ×4

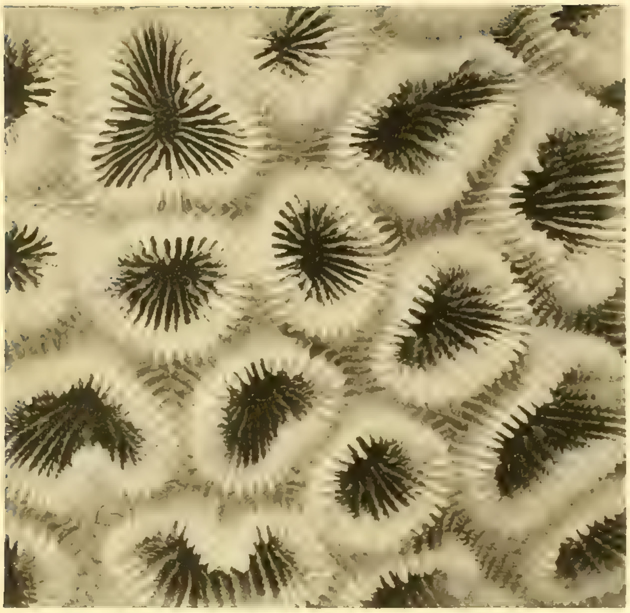


3 ×4

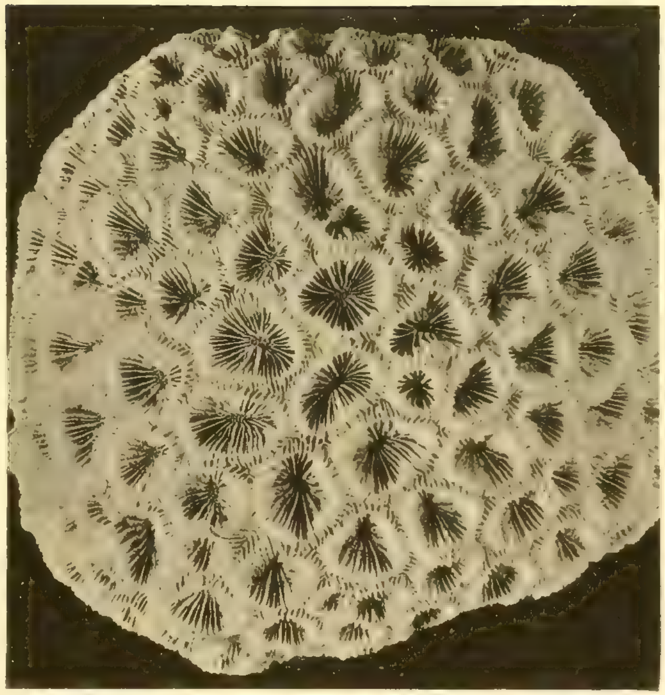


4 ×4

FIGS. 1, 1*a*, 2, 2*a*, 3. *Favia stelligera* (Dana). FIG. 4. *Favia stelligera* var. *fanningensis*, new var.



1 ×2



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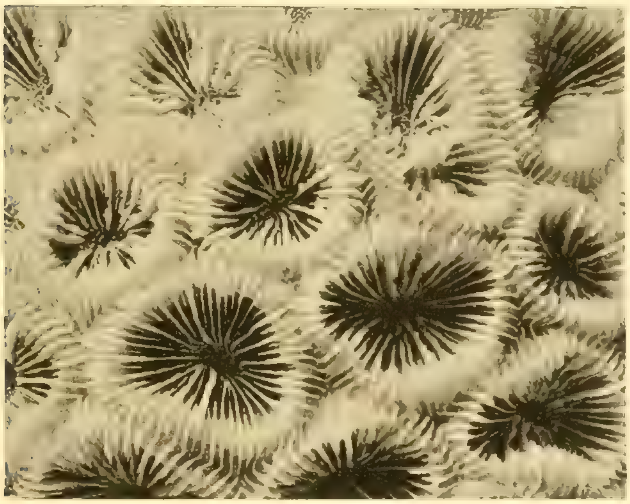
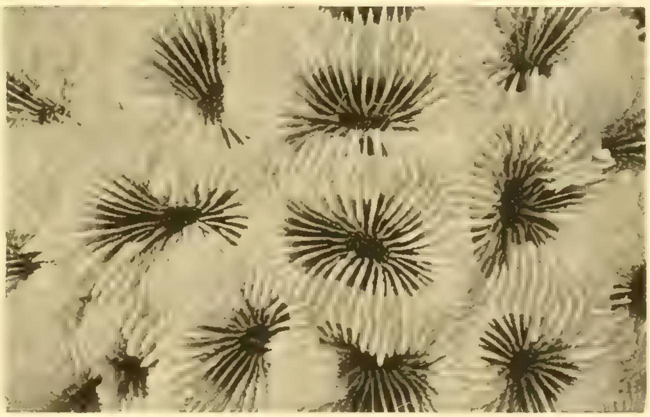
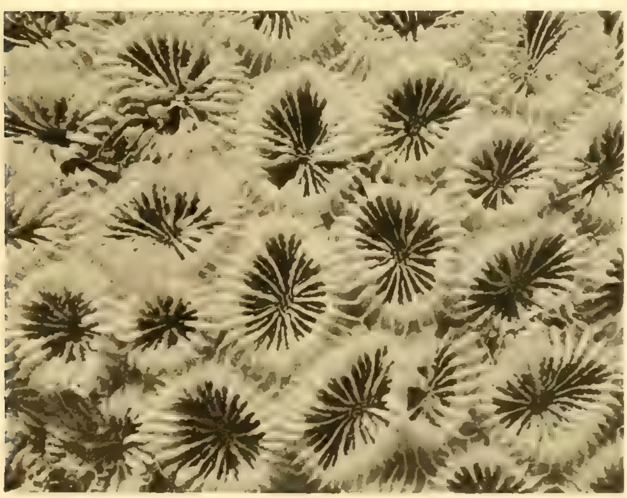


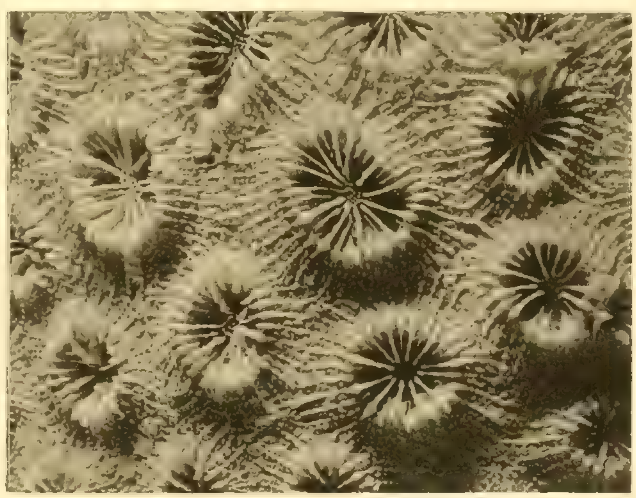
2[a] ×2



3 ×2

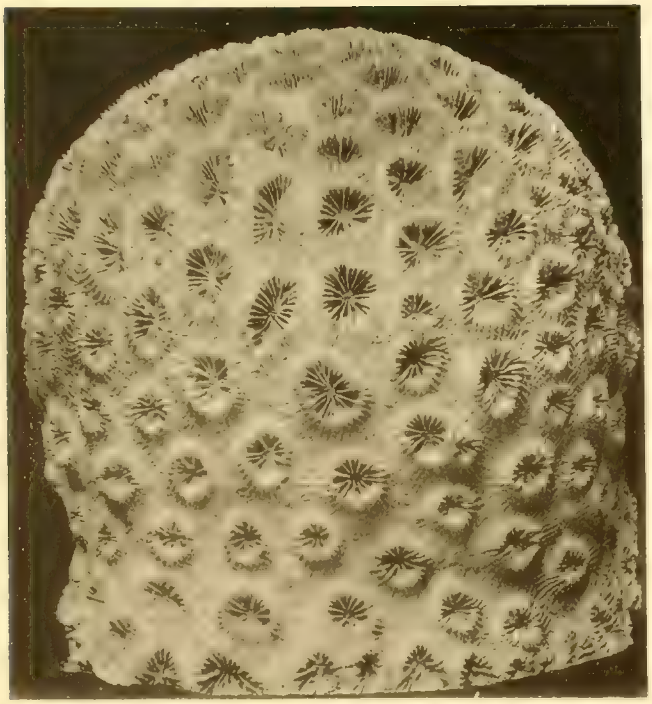


4 ×2



4[a] ×2

Favia speciosa (Dana).



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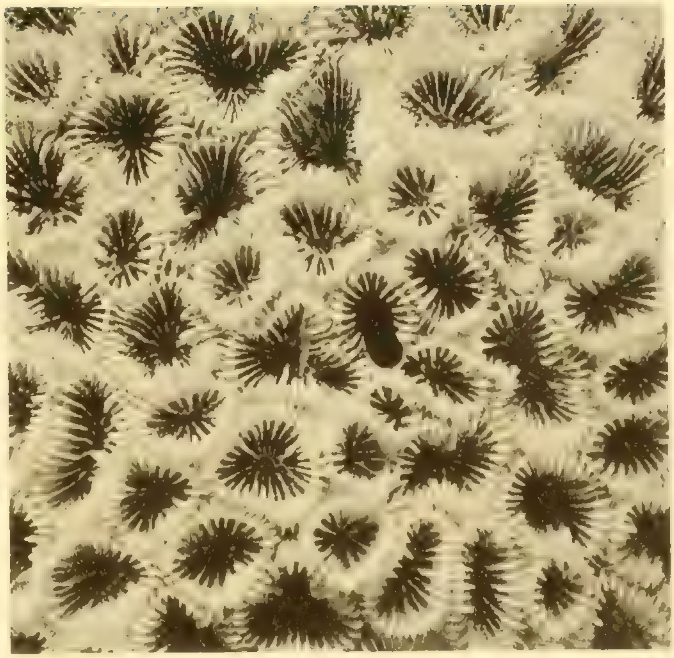
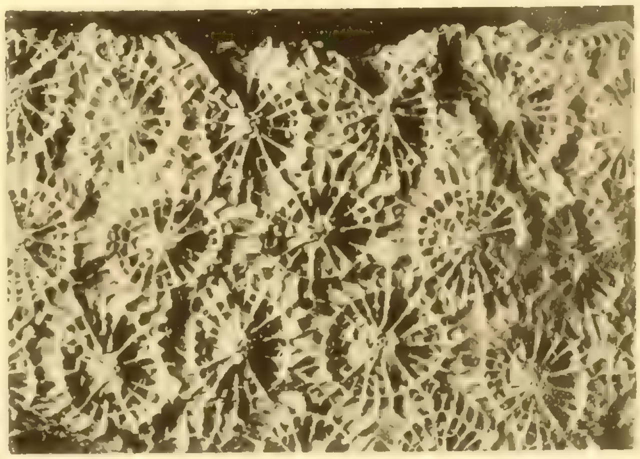
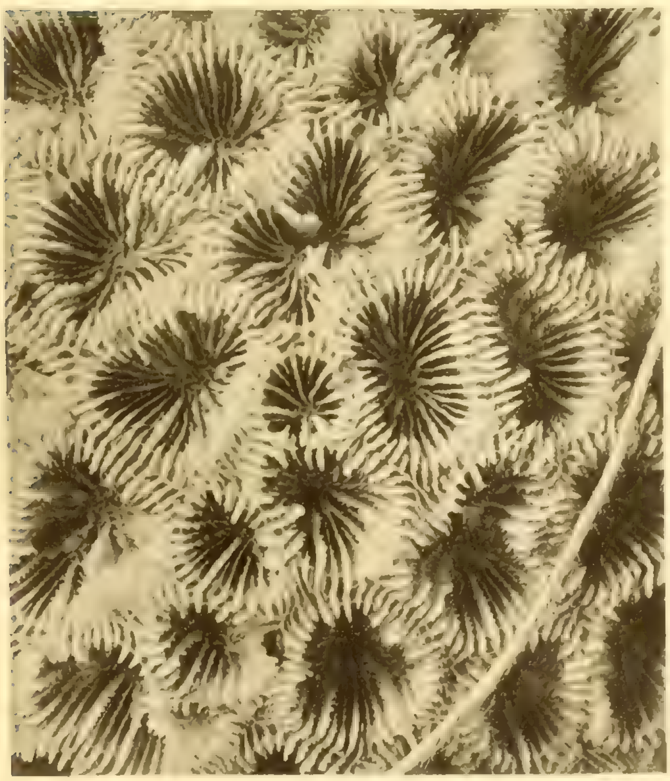


2 × 2



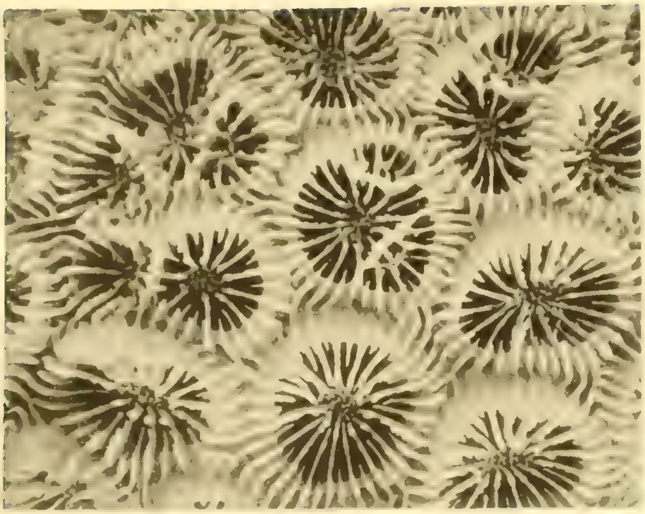
4 × 2



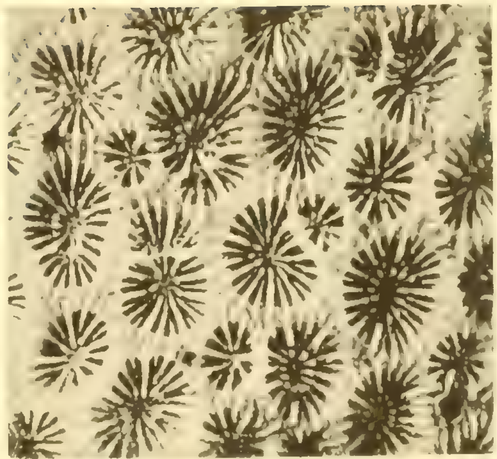
3

4a × 2

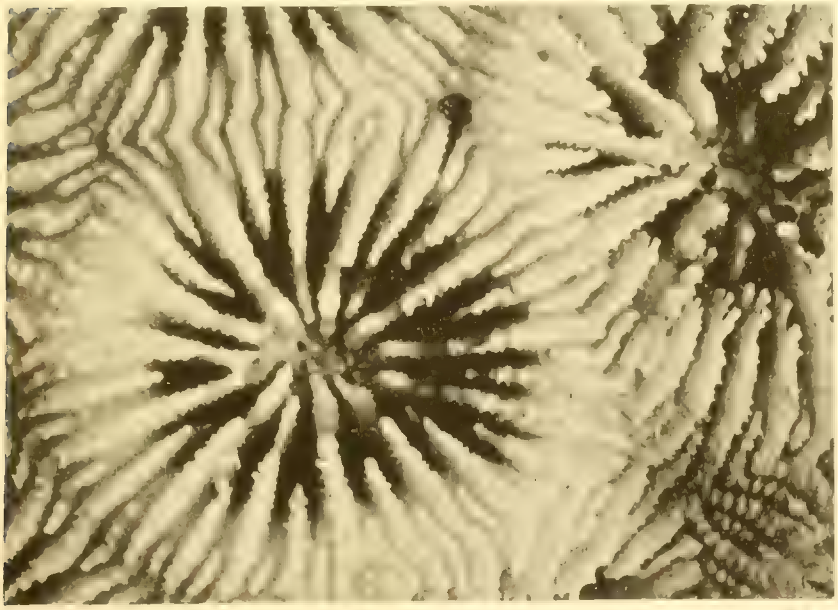
[illegible]ia (Dana).



1 ×2

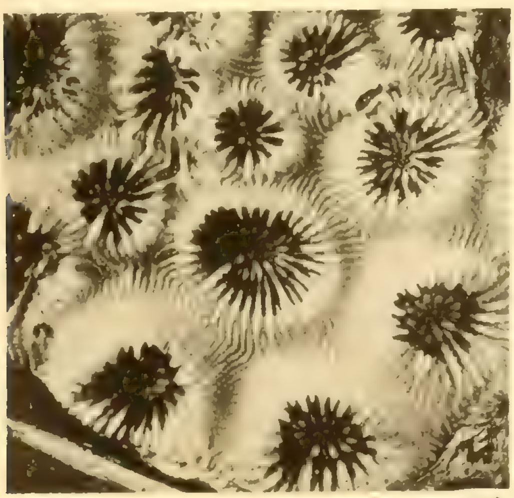


2 ×2

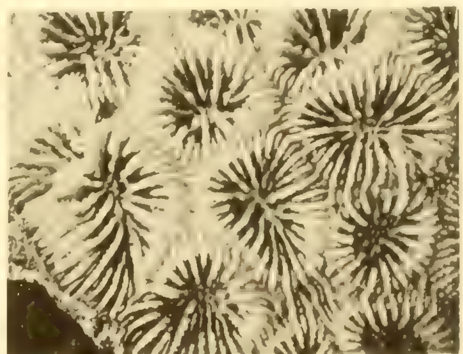


3 ×6

4 ×2



5 ×2

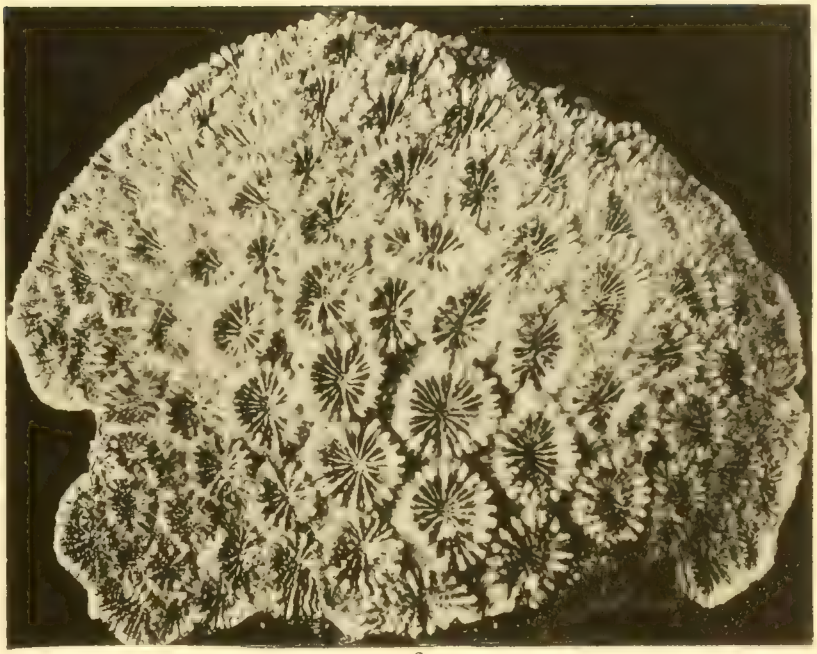


6 ×2

7 ×2

Favia pallida (Dana).

1



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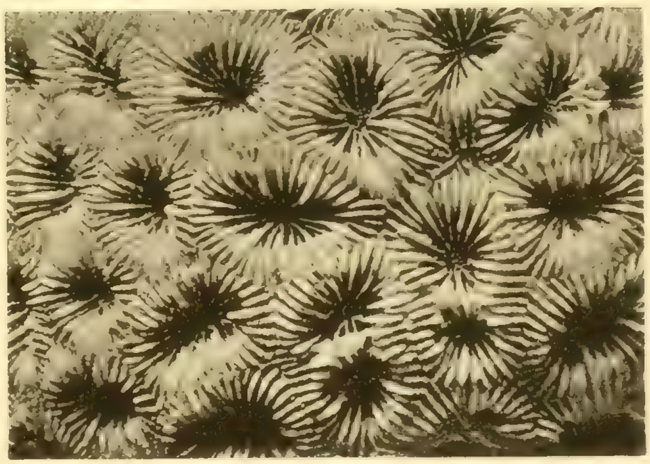
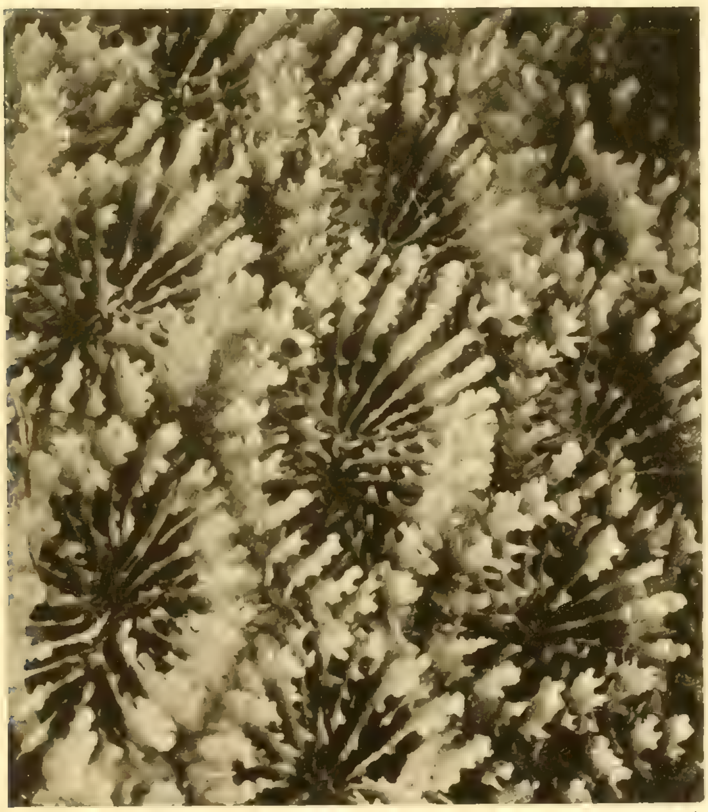
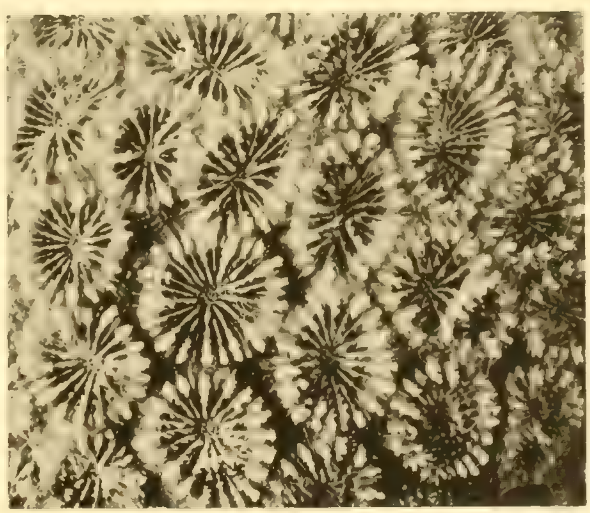


1a ×2

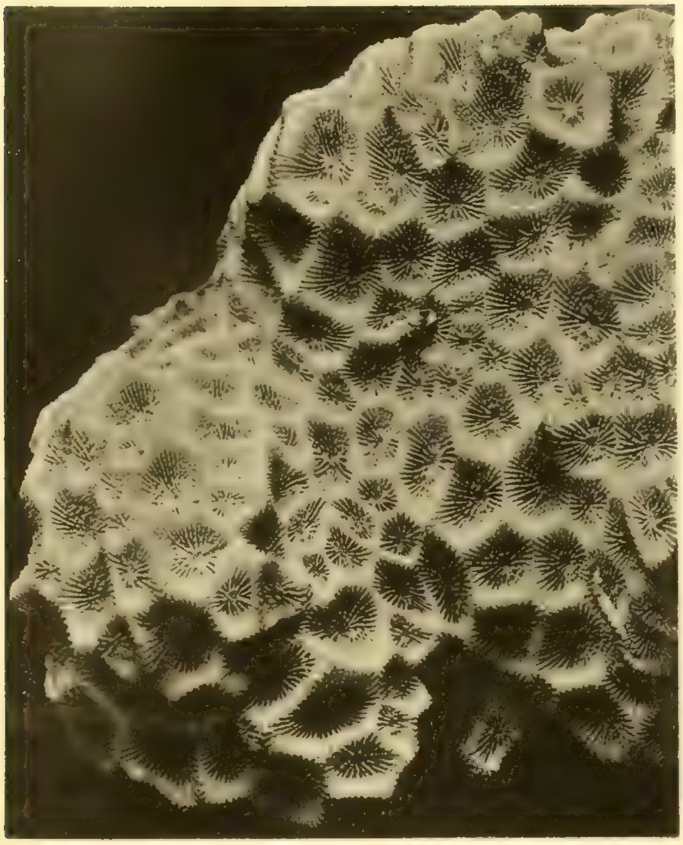


2b ×4

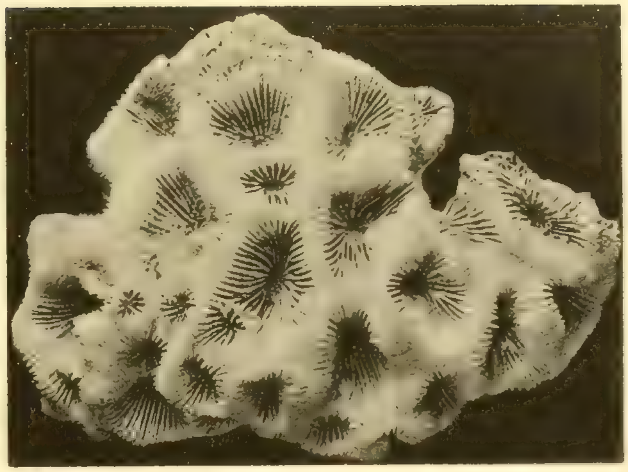


2a ×2

Figs. 1, 1*a*. *Favia danæ* Verrill. Figs. 2, 2*a*, 2*b*. *Favia matthaii*, new species.



1



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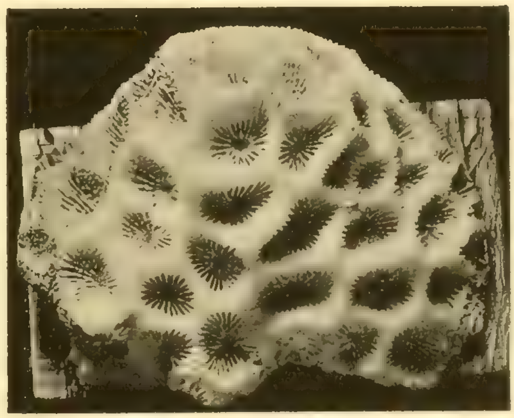

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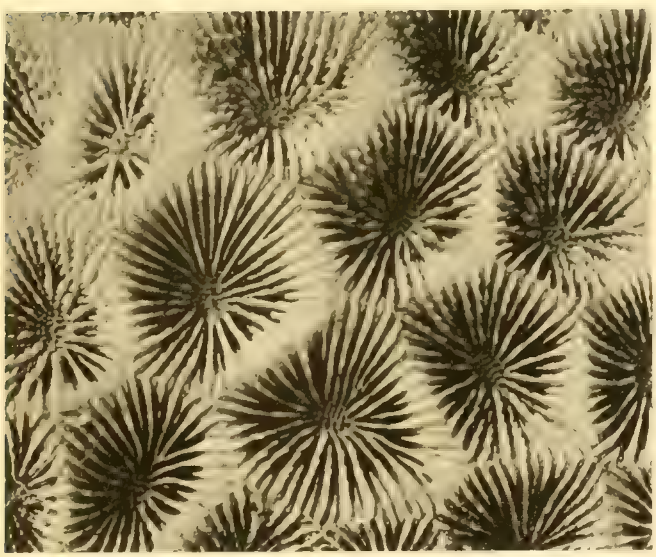
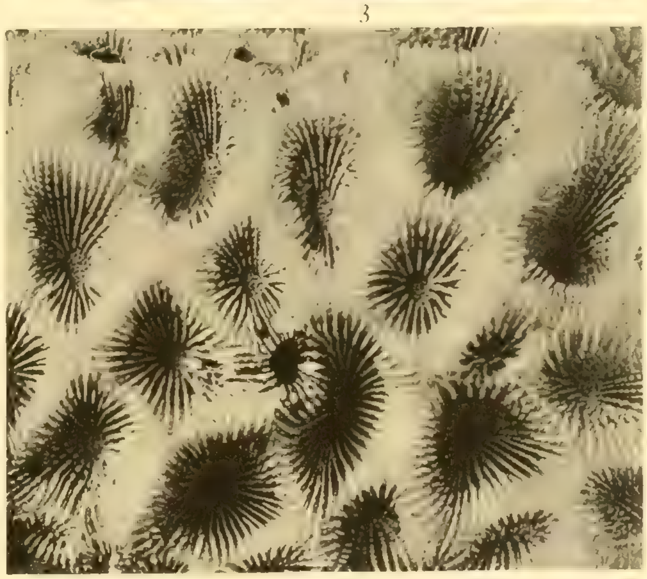
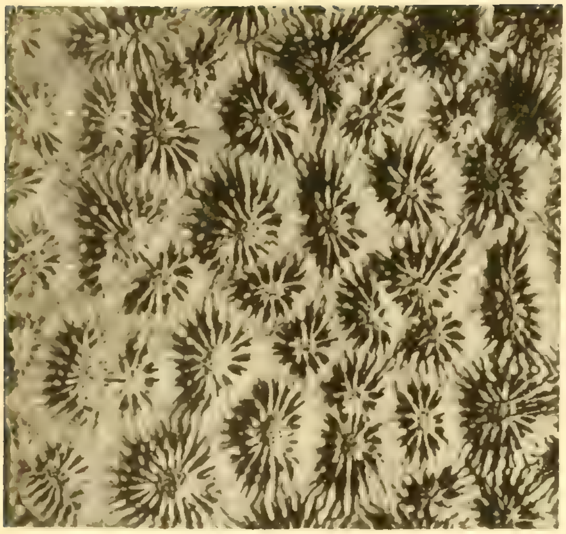


4 ×2

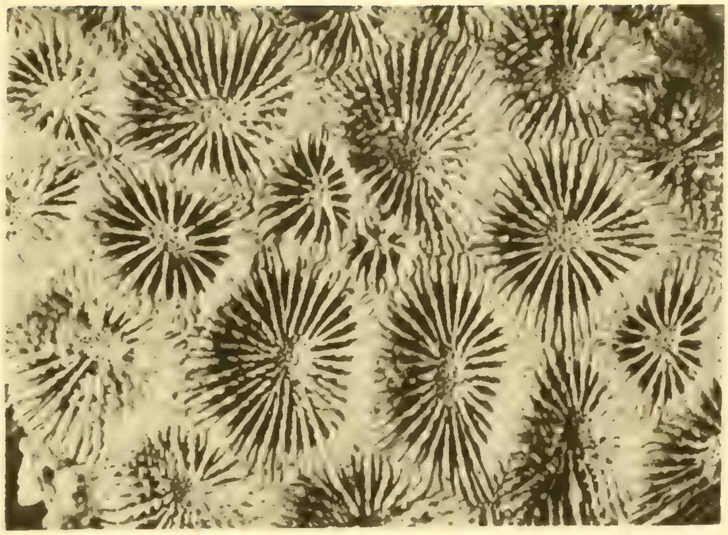


5 ×2

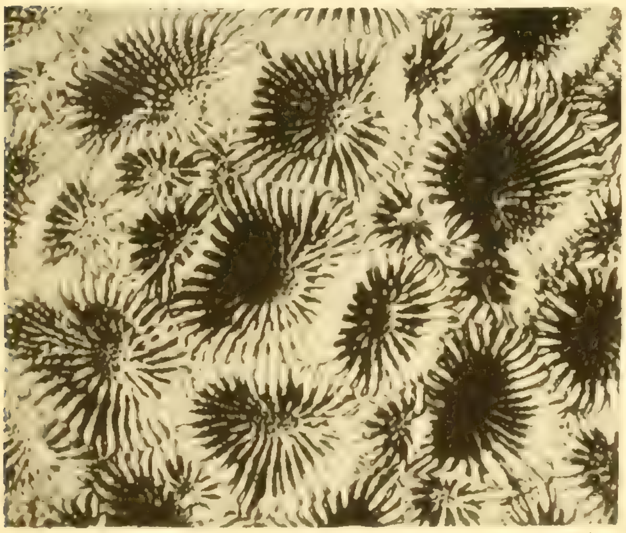
Favites abdita (Ell. and Sol.).



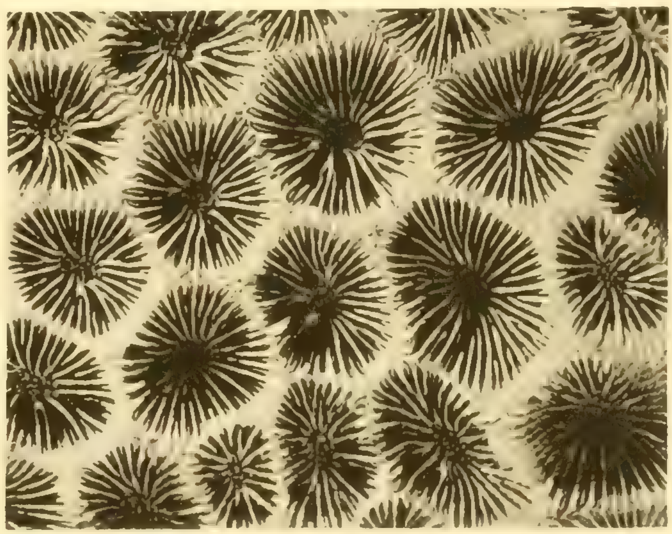
1 × 2



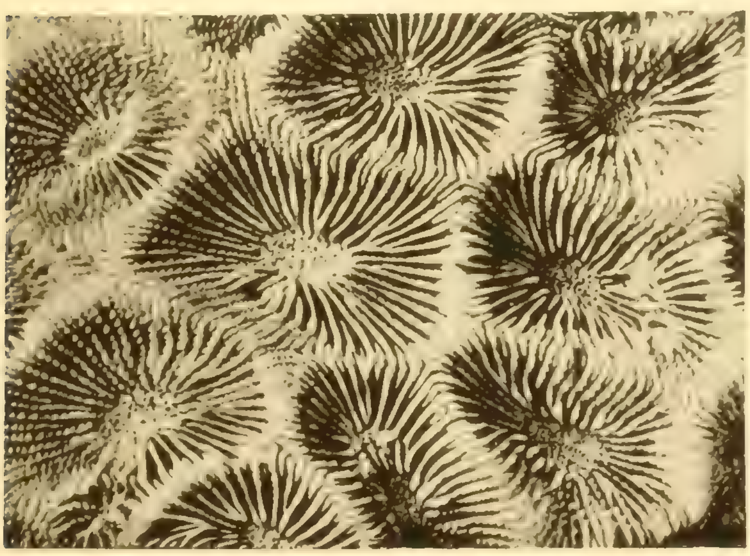
2 × 2



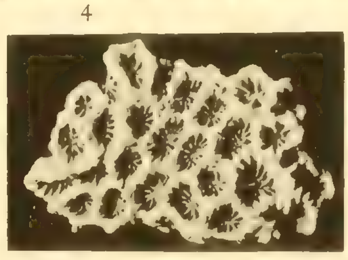
3 × 2



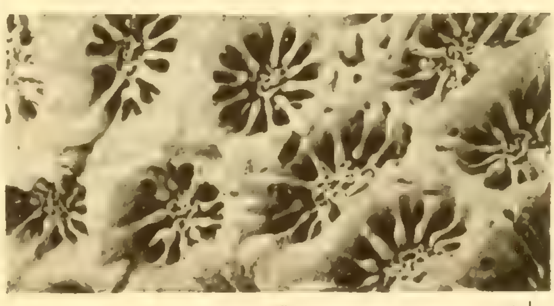
4 × 2



5 × 2



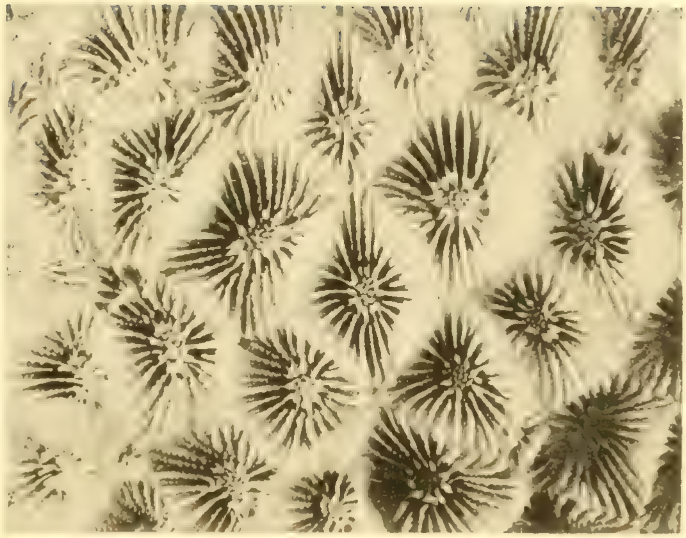
6



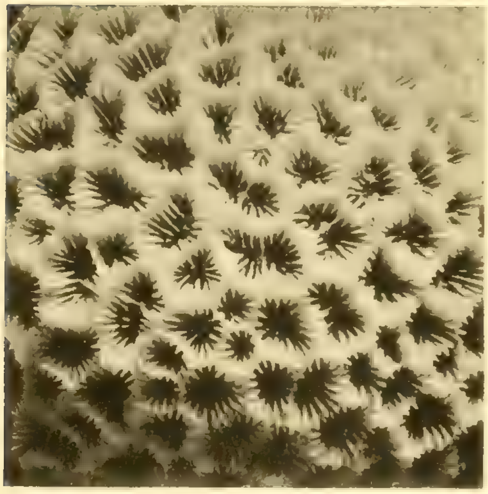
6a × 4

FIGS. 1-3. *Favites halicora* (Ehr.). FIGS. 4, 5. *Favites virens* (Dana). FIGS. 6, 6*a*. *Favites melicerum* (Ehr.).

1 ×2½

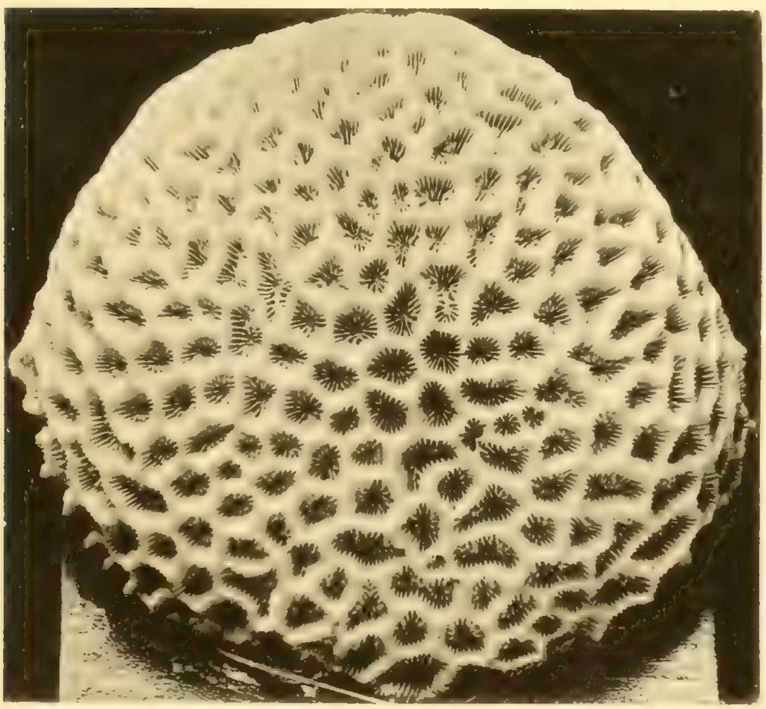


2 ×2½

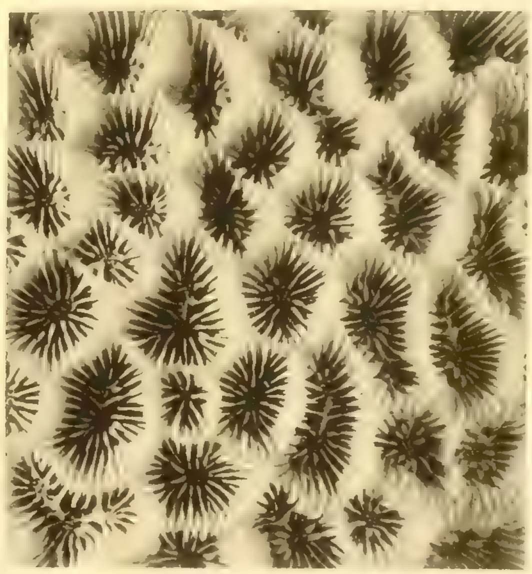


3a ×2

3

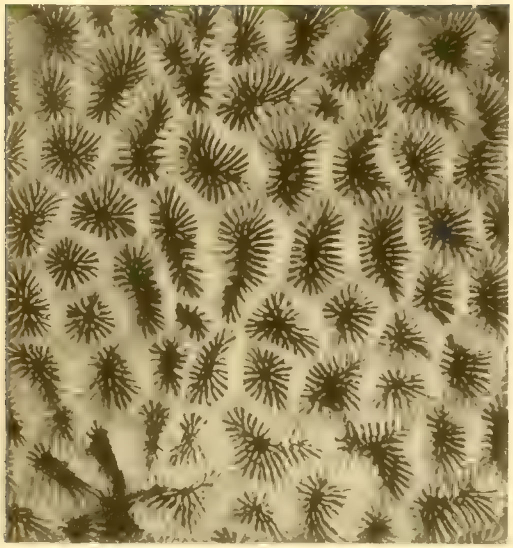


4

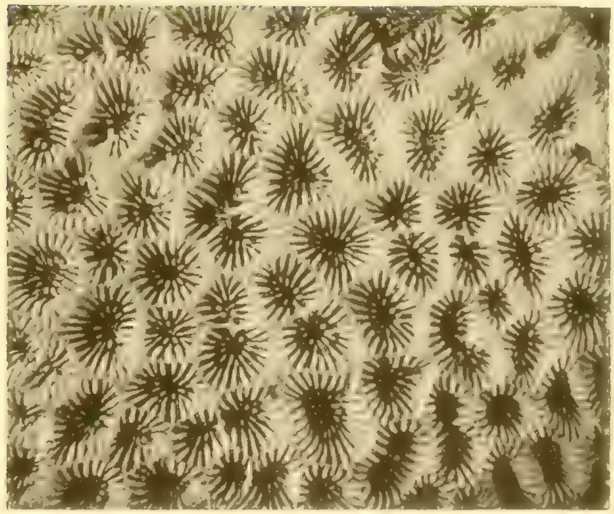


4a ×2

FIGS. 1, 2. *Favites pentagona* (Esper). FIGS. 3, 3*a*, 4, 4*a*. *Goniastrea pectinata* (Ehr.).

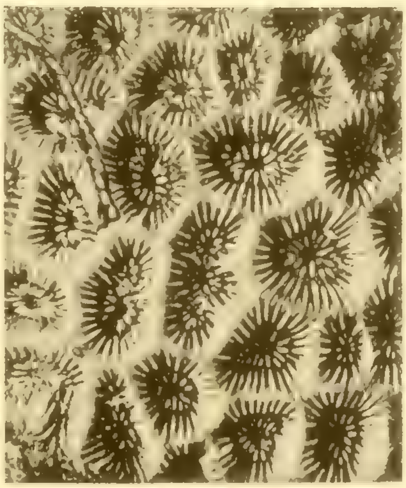


1 ×2

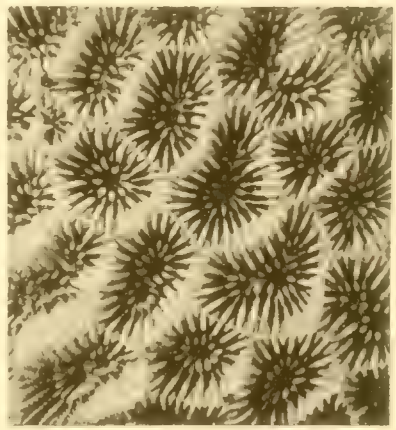


2 ×2

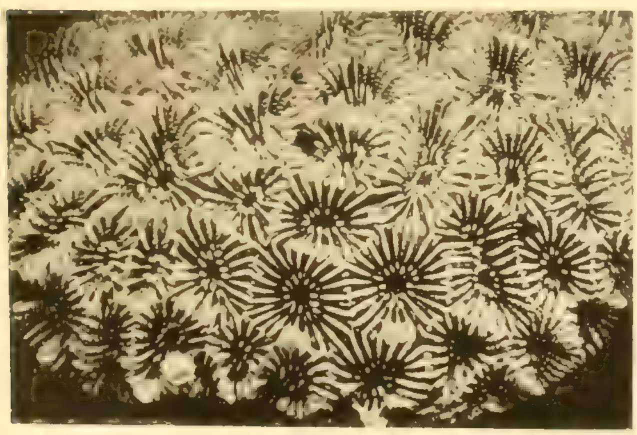
3 ×2



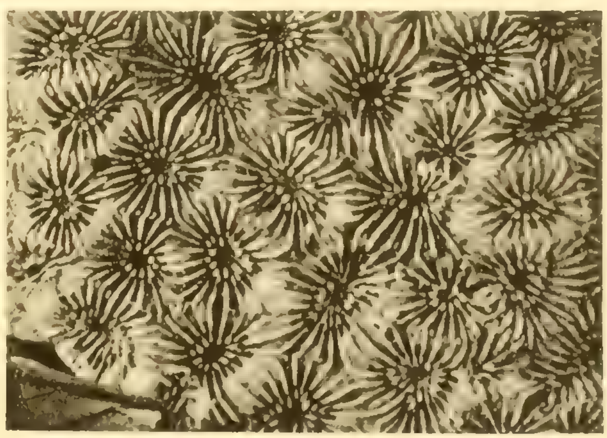
3a ×2



4 ×2

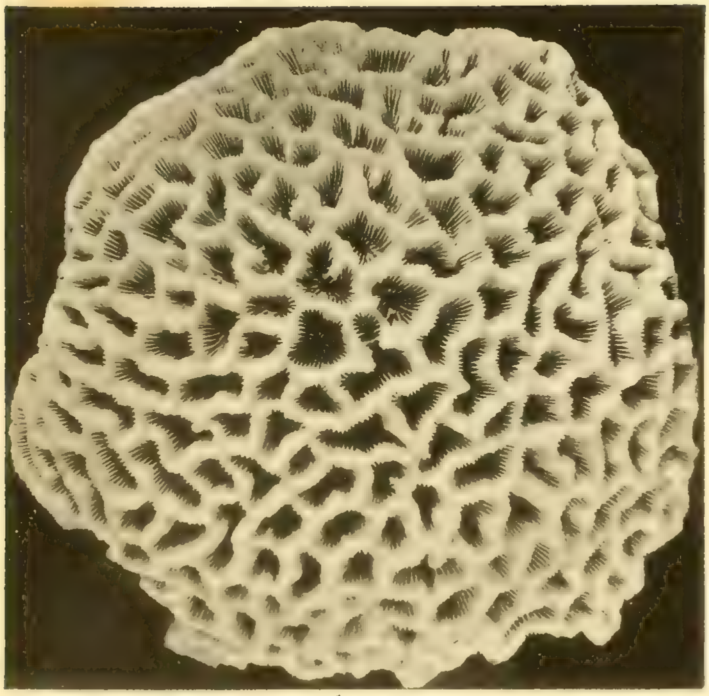


5 ×2



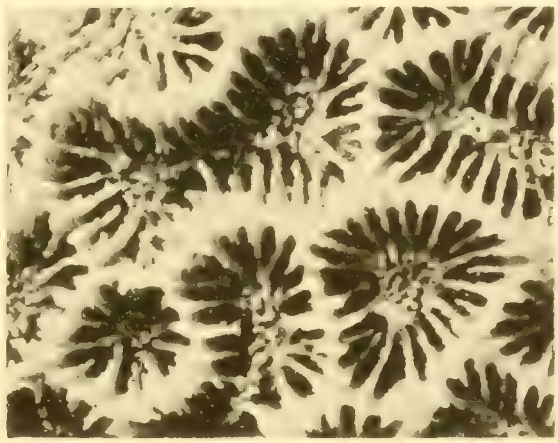
5a ×2

Goniastrea pectinata (Ehr.).

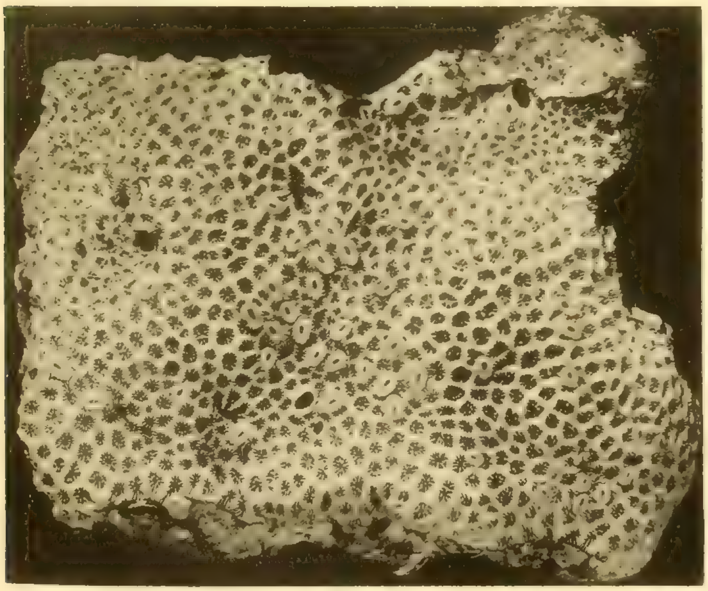


1

1a ×2

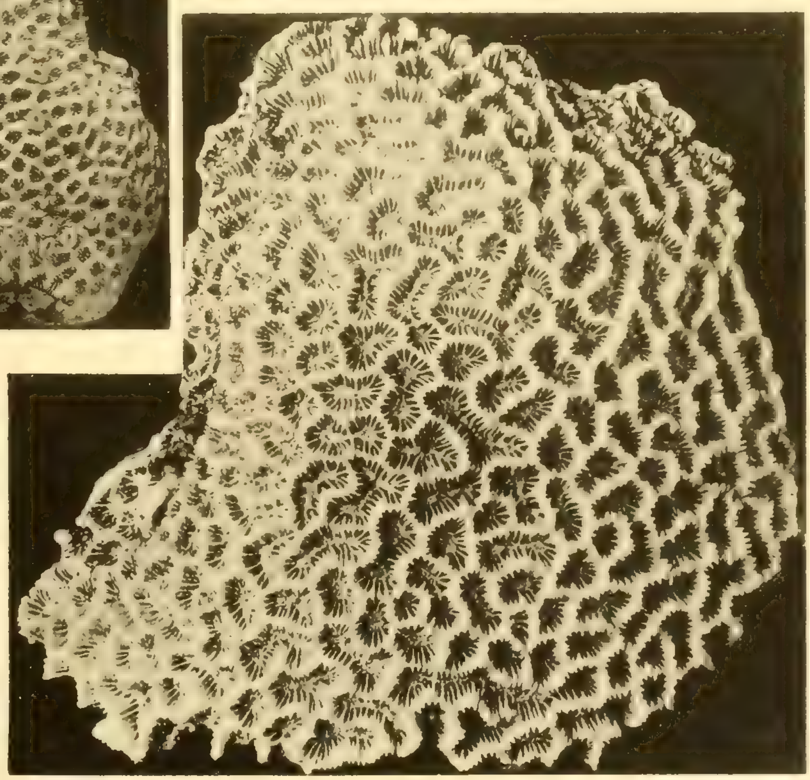


3a ×4



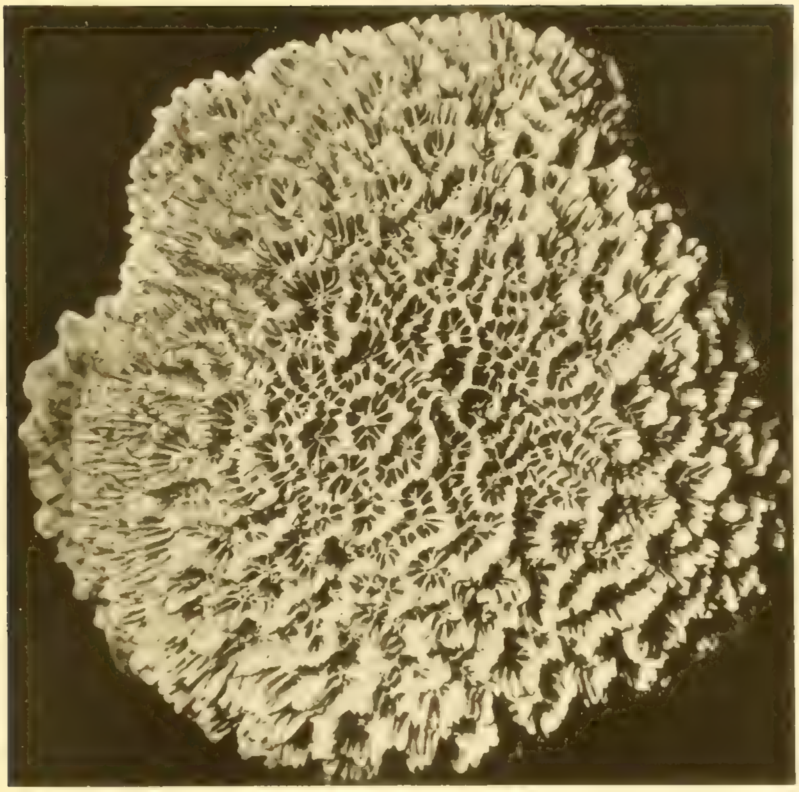
2

2a ×4

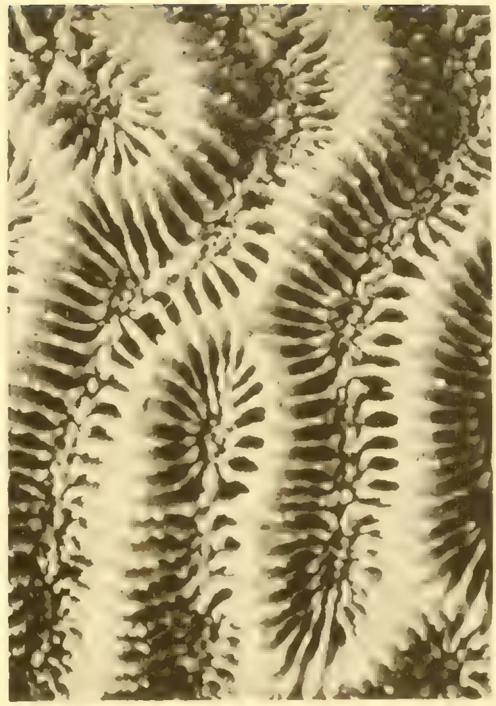


3

Figs. 1, 1*a*. *Favites spectabilis* (Verrill). Figs. 2, 2*a*. *Goniastrea parvistella* (Dana).
Figs. 3, 3*a*. *Mœandra dœdalea* (Ell. and Sol.).



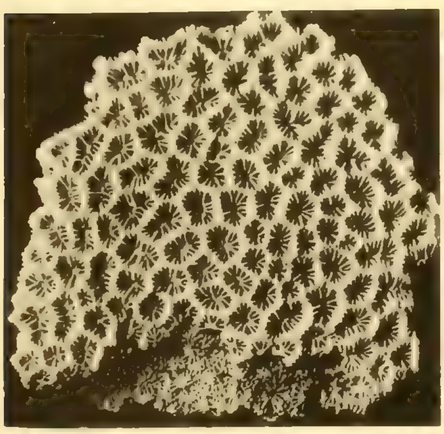
1



2a ×4

2

3a ×4



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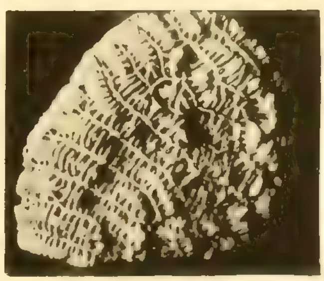

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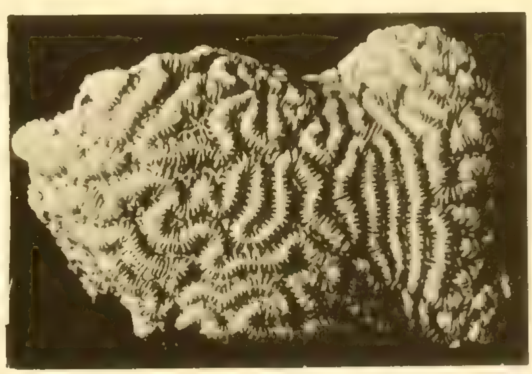
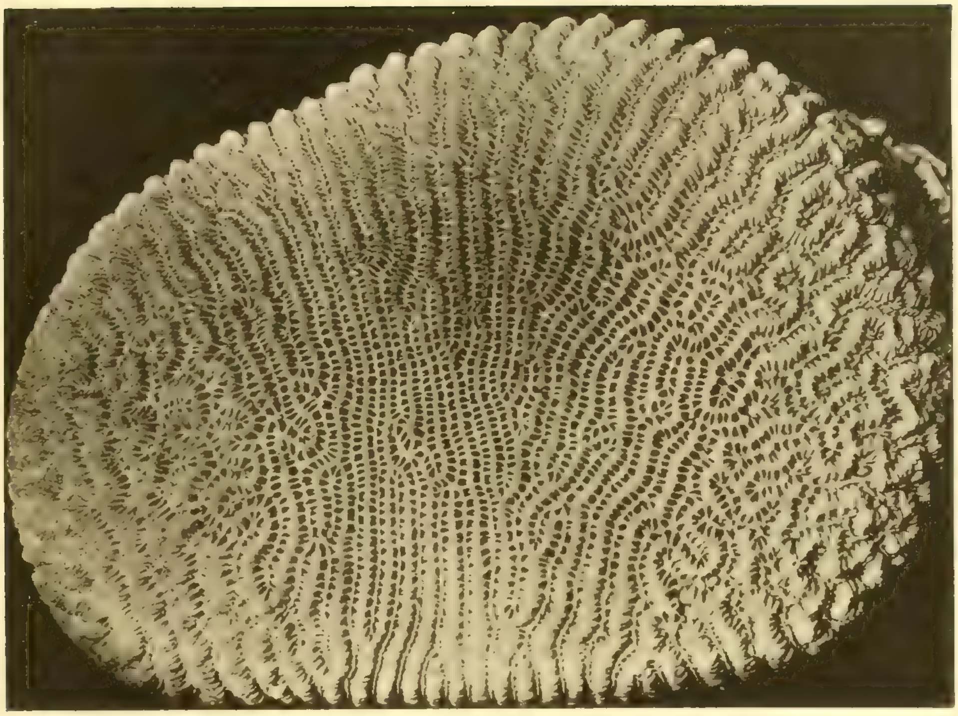
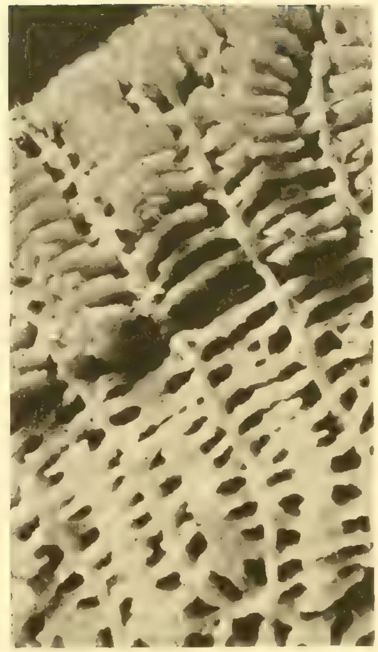


5

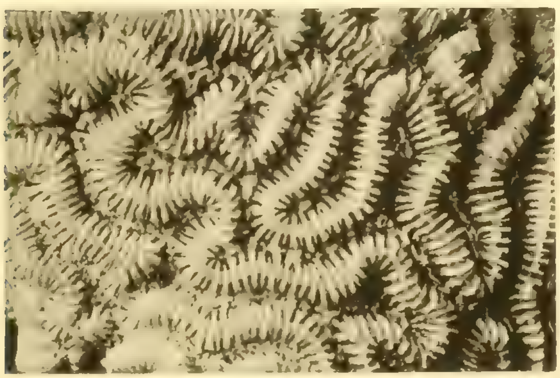
FIG. 1. *Mæandra dædalea* (Ell. and Sol.).
FIGS. 2, 2*a*. *Mæandra lamellina* Ehr.
FIGS. 3, 3*a*. *Mæandra stricta* (M. Edw. and H.).
FIGS. 4, 5. *Leptoria phrygia* (Ell. and Sol.).



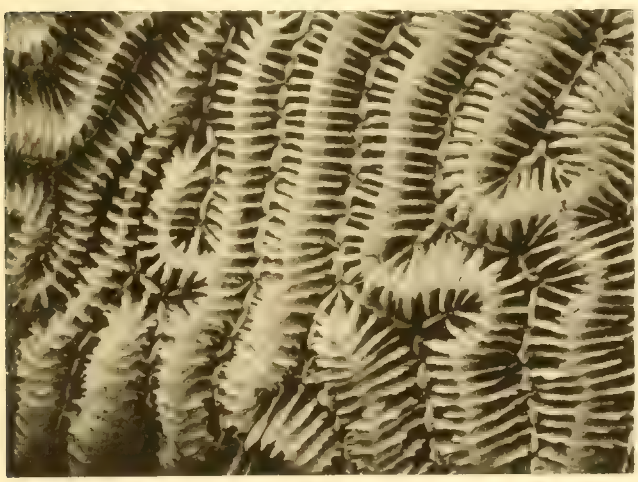
1



2 ×4



3 ×2

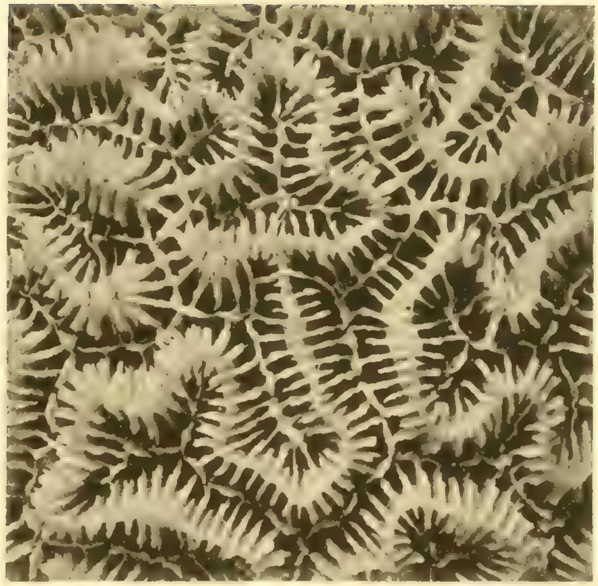


4a ×3

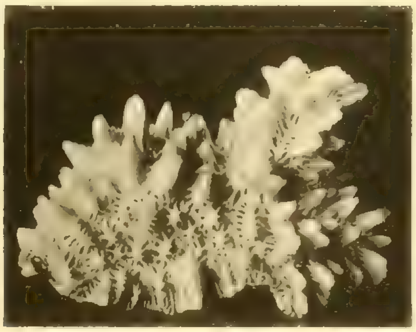
4

FIGS. 1, 2, 3. *Leptoria phrygia* (Ell. and Sol.). FIGS. 4, 4*a*. *Leptoria gracilis* (Dana).

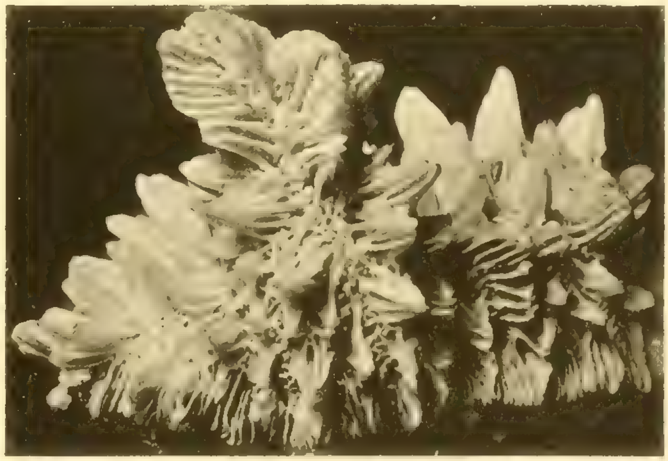
1



1a ×3

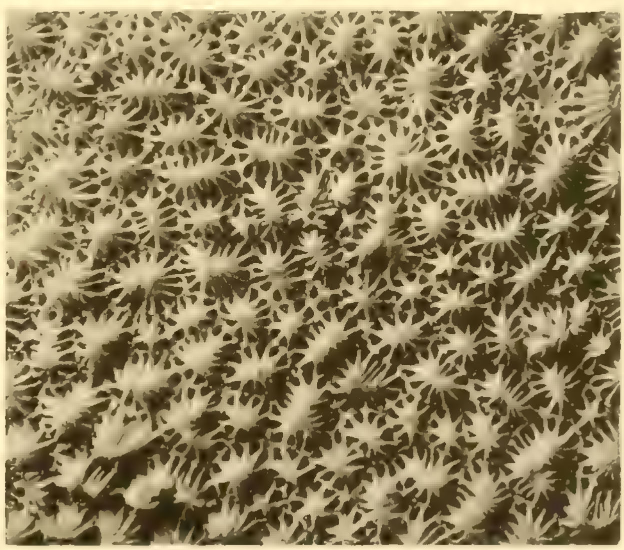


2



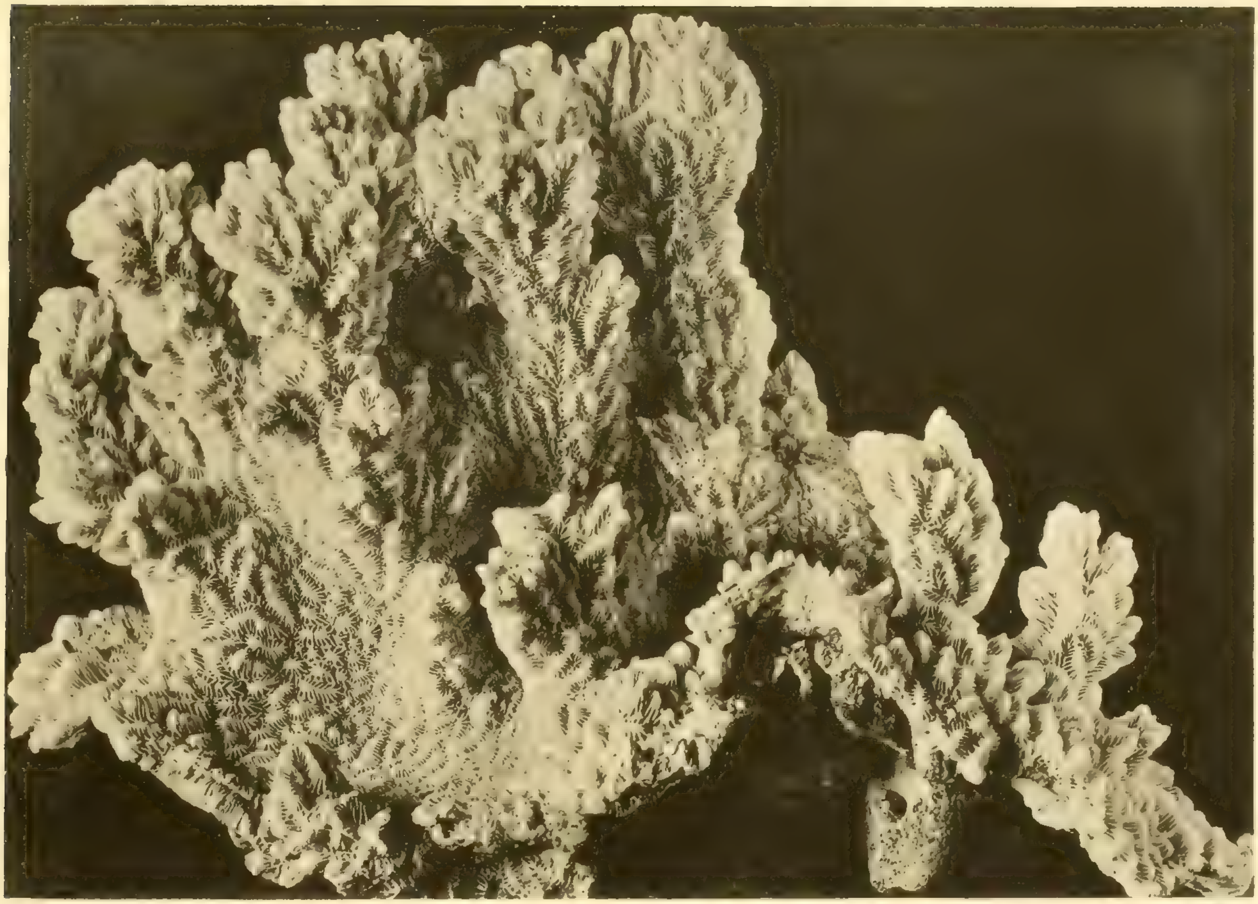
2a ×2

3 ×½

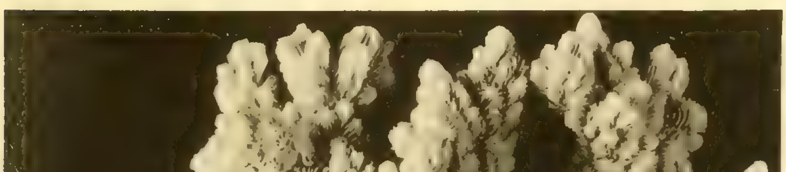


3a ×2

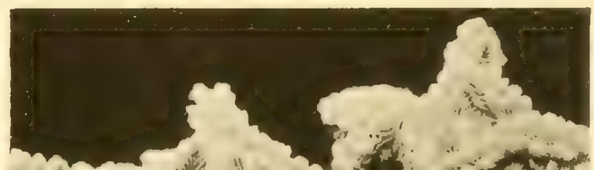
FIGS. 1, 1*a*. *Leptoria tenuis* (Dana). FIGS. 2, 2*a*. *Hydnophora exesa* (Pall.).
FIGS. 3, 3*a*. *Hydnophora microconos* (Lam.).



1 $\times \frac{9}{20}$

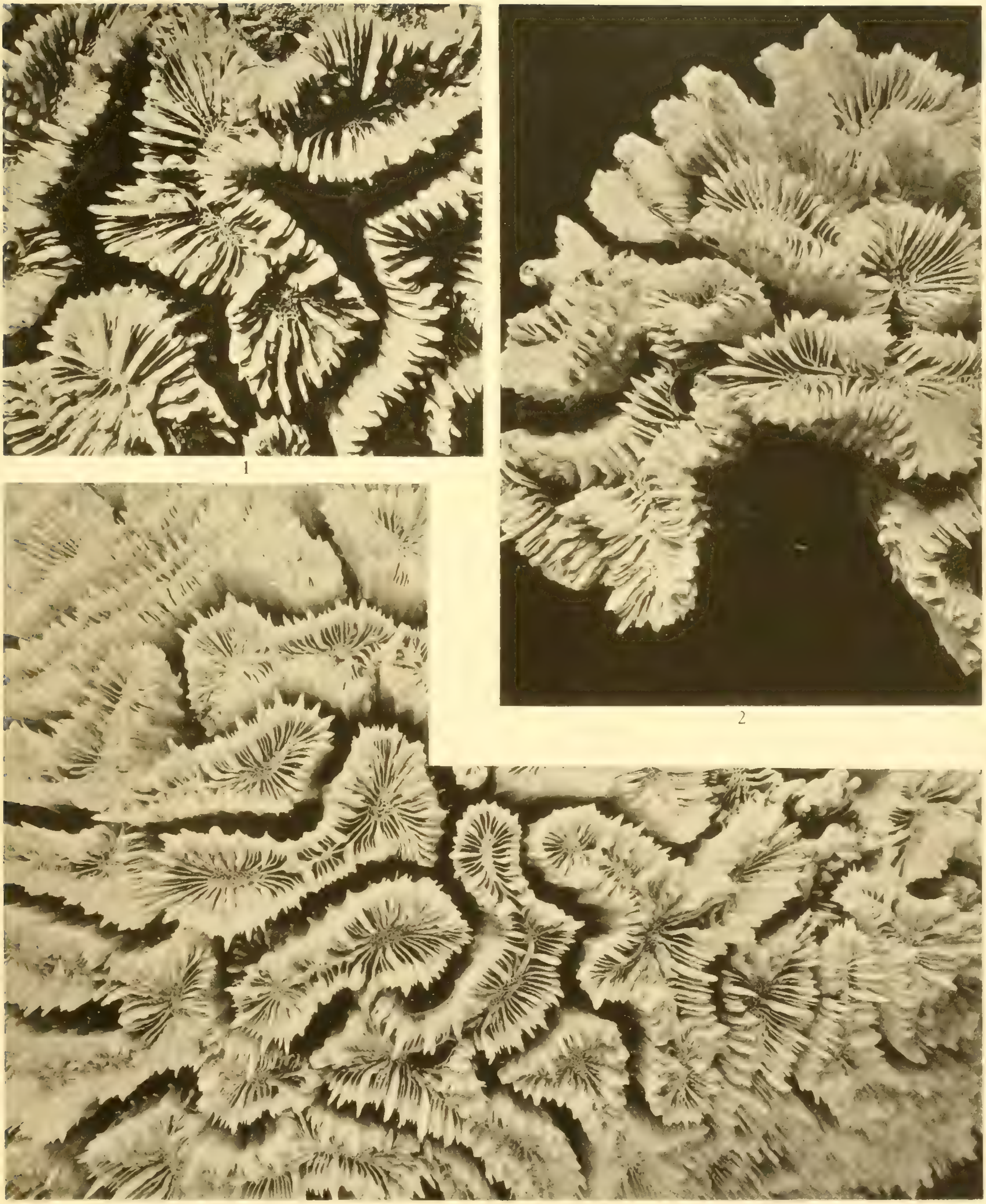


2 $\times \frac{9}{10}$



3 $\times \frac{9}{10}$

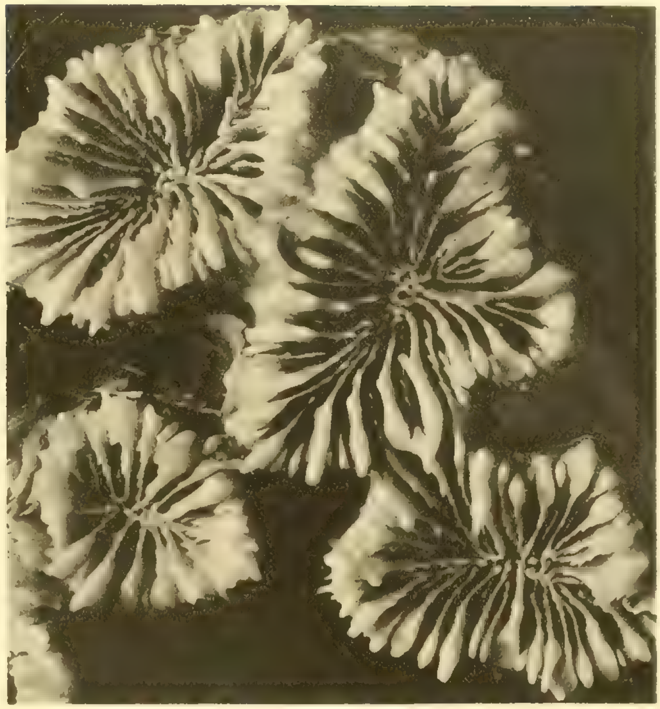
FIG. 1. *Hydnophora exesa* (Pall.). FIGS. 2, 3. *Hydnophora rigida* (Dana).



1 2 3

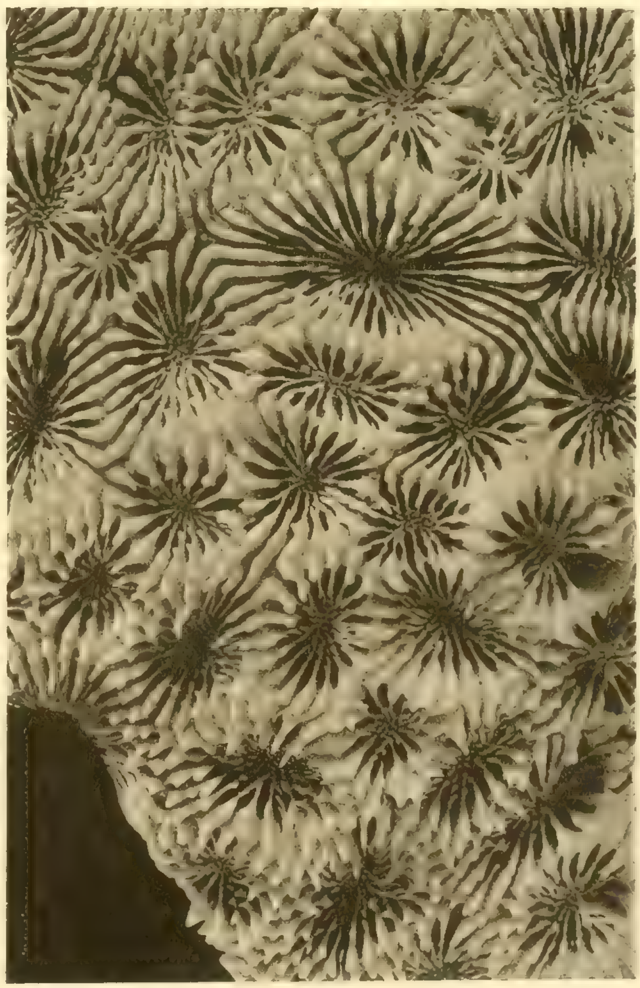
Mussa sinuosa (Lam.).

1

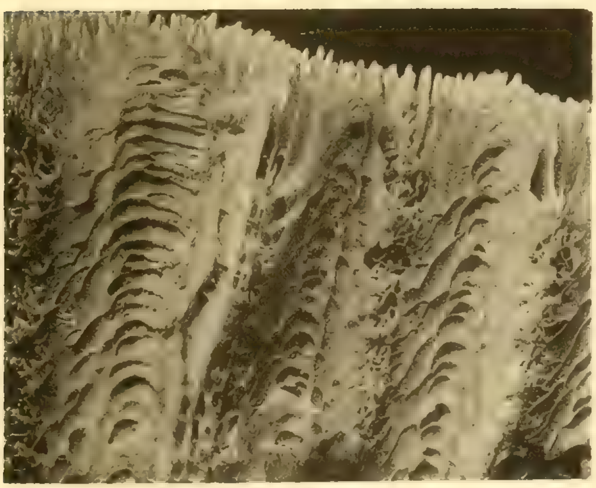


1b ×2

1a

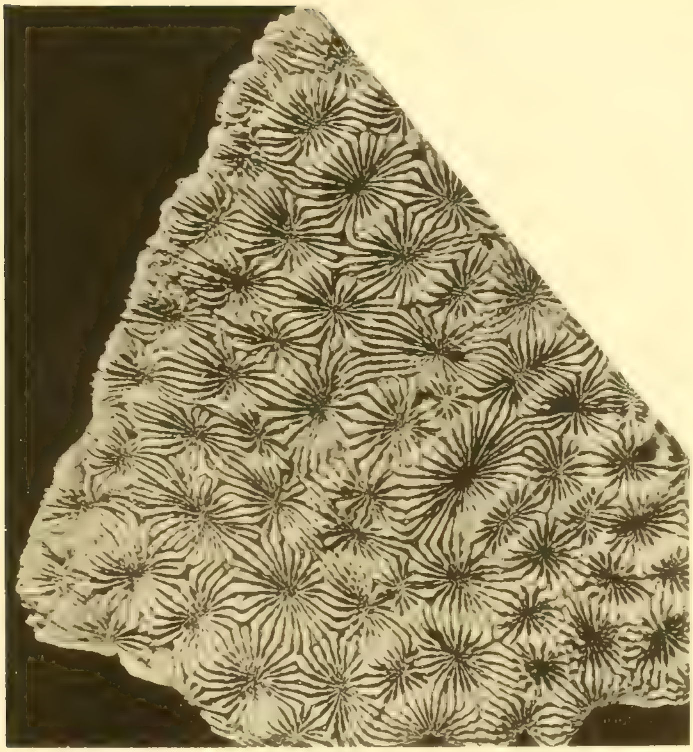


2 ×2

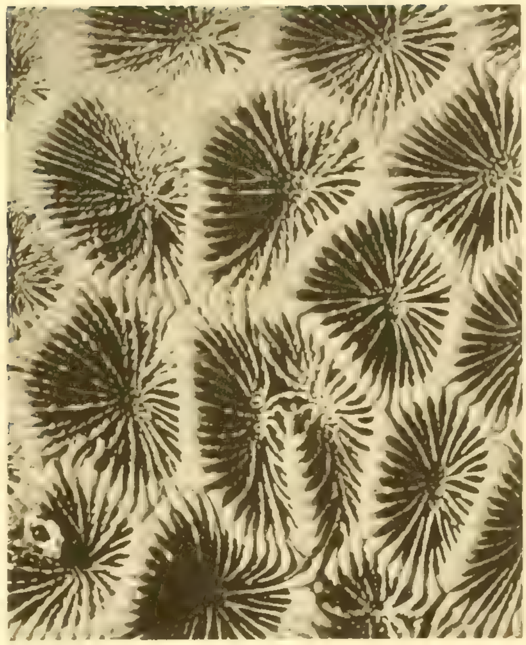


2a ×2

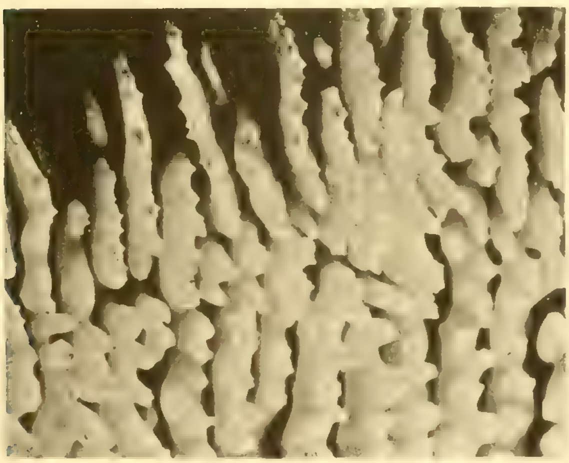
FIGS. 1, 1*a*, 1*b*. *Mussa sinuosa* (Lam.). FIGS. 2, 2*a*. *Acanthastrea echinata* (Dana).



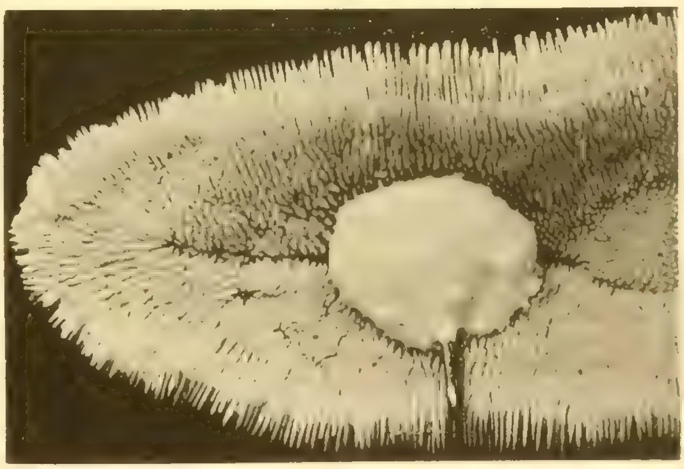
1



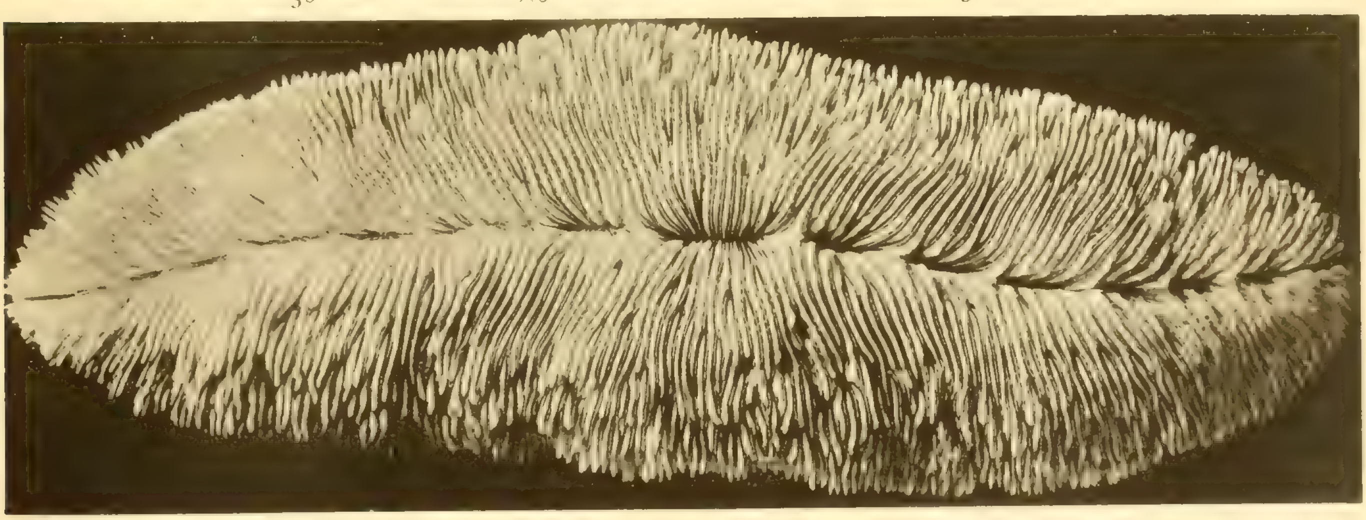
2 × 2



3b ×6

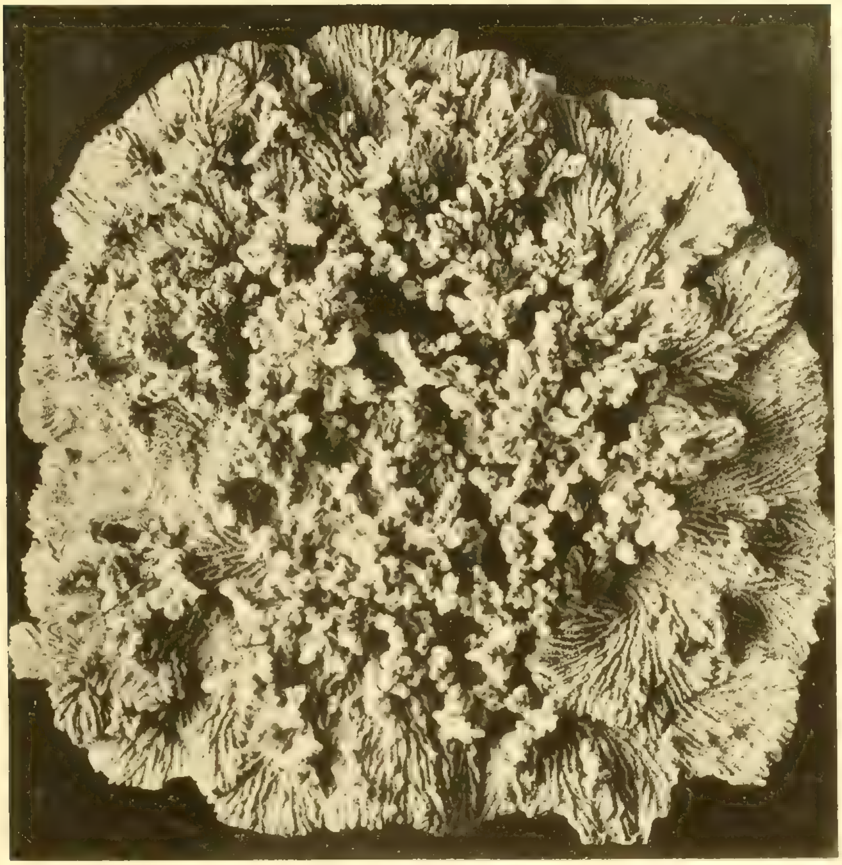


3a



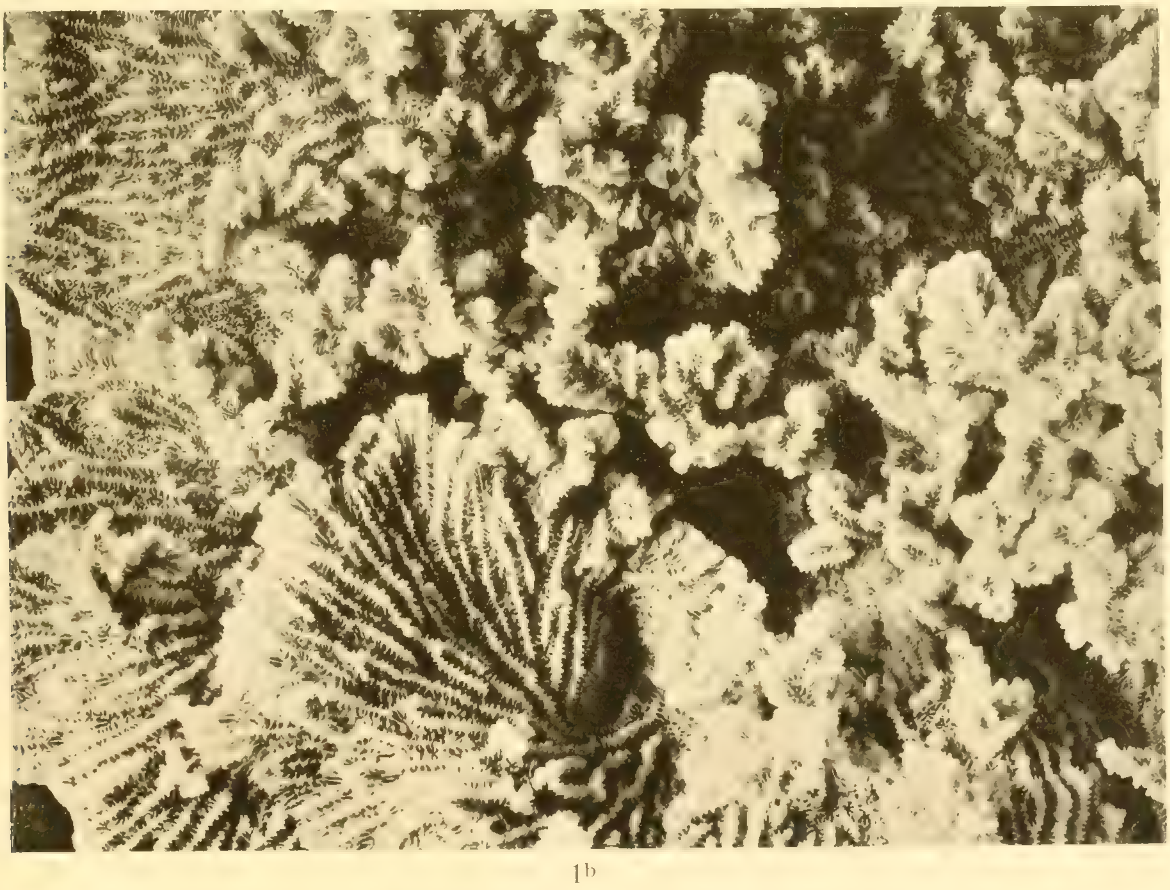
3

FIGS. 1, 2. *Acanthastrea echinata* (Dana). FIGS. 3, 3*a*, 3*b*. *Herpetolitha stricta* (Dana).



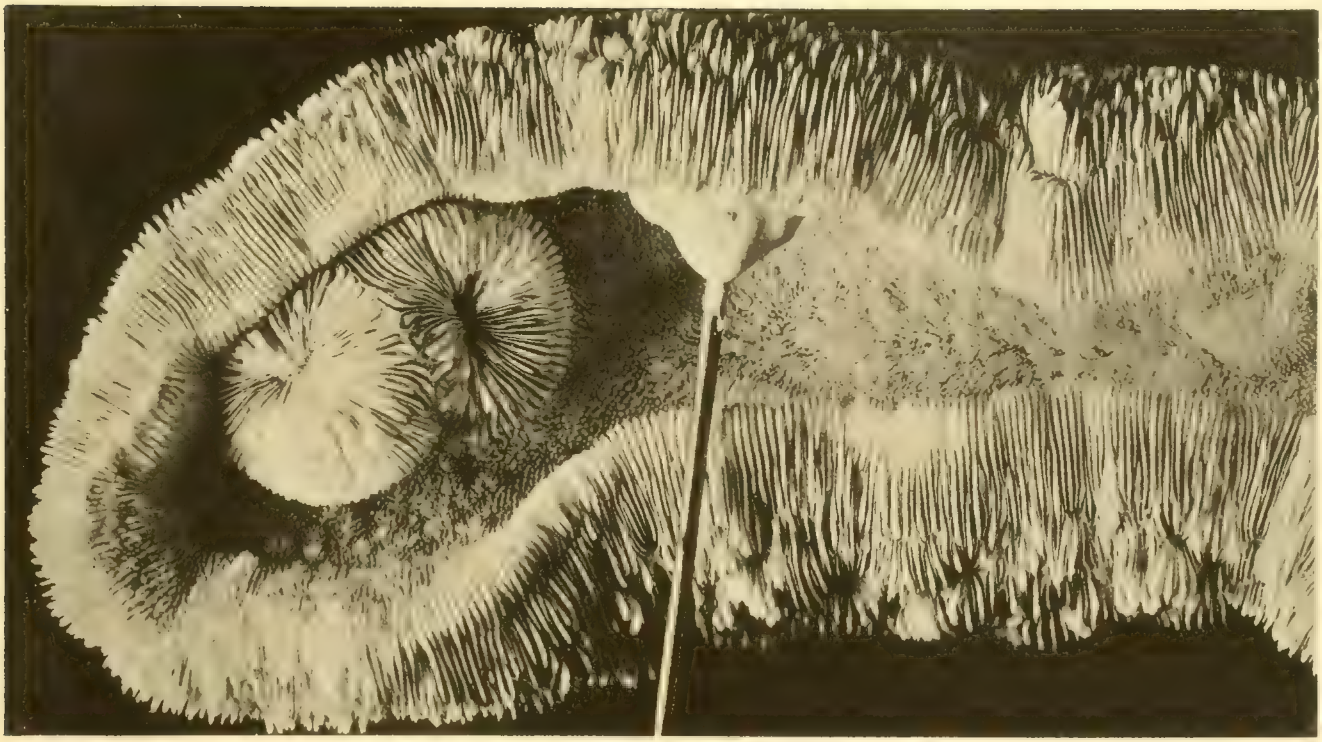
1 $\times \frac{1}{3}$

1a $\times \frac{1}{3}$

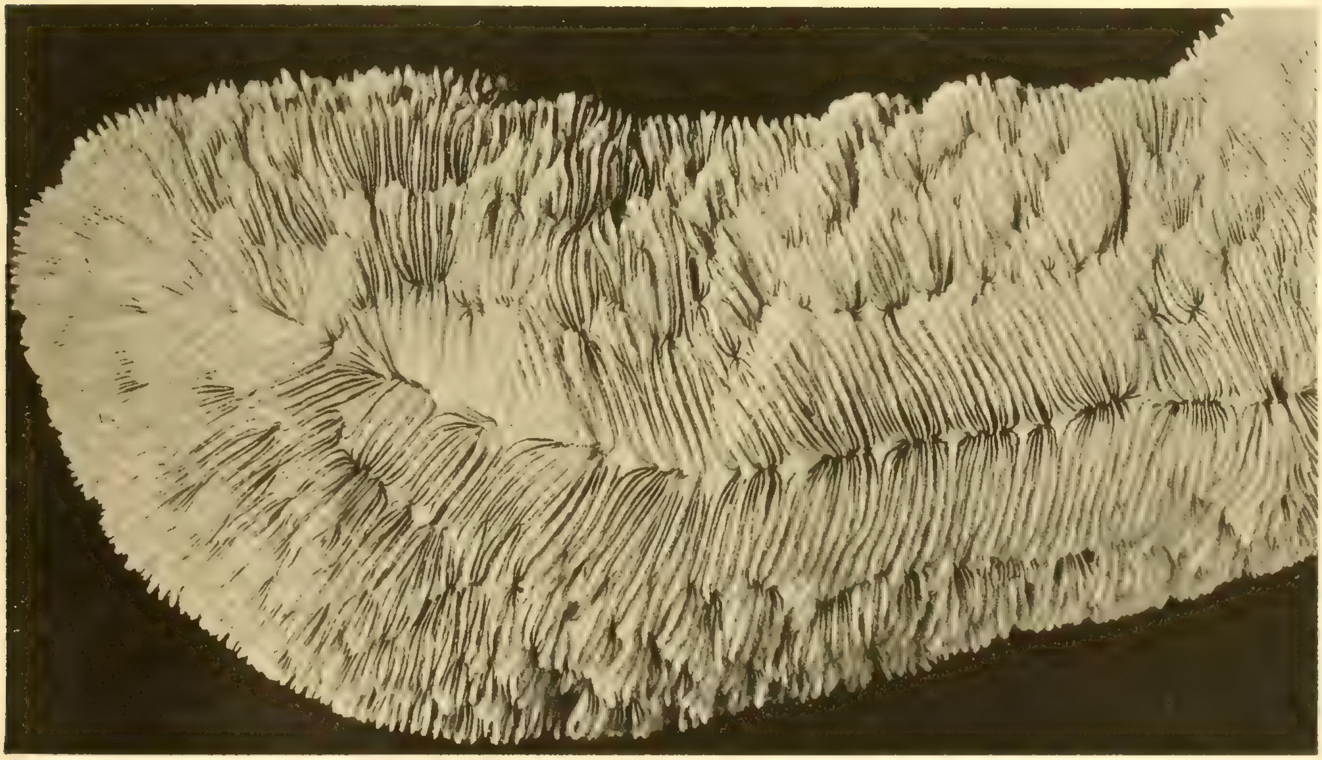


1b

Merulina ampliata (Ell. and Sol.).

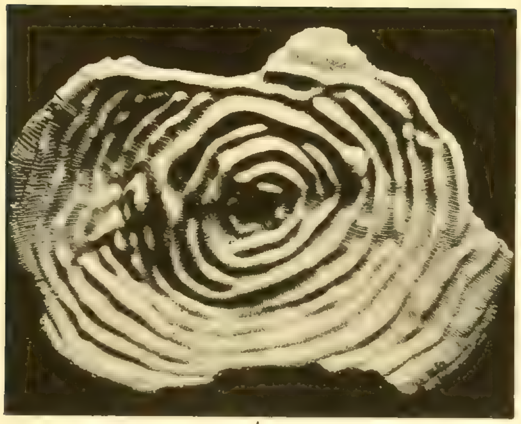


1[a]



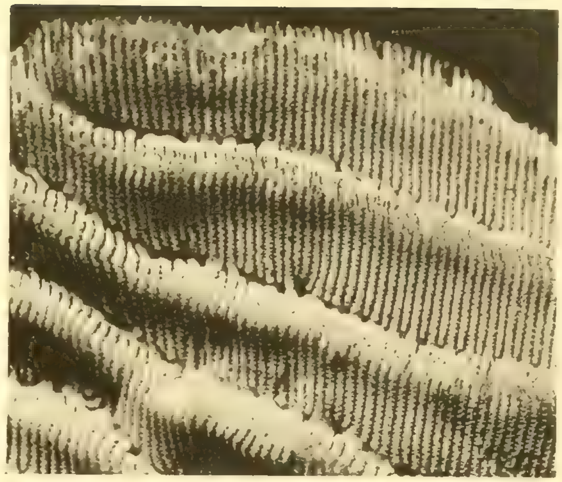
1

Herpetolitha crassa Dana.

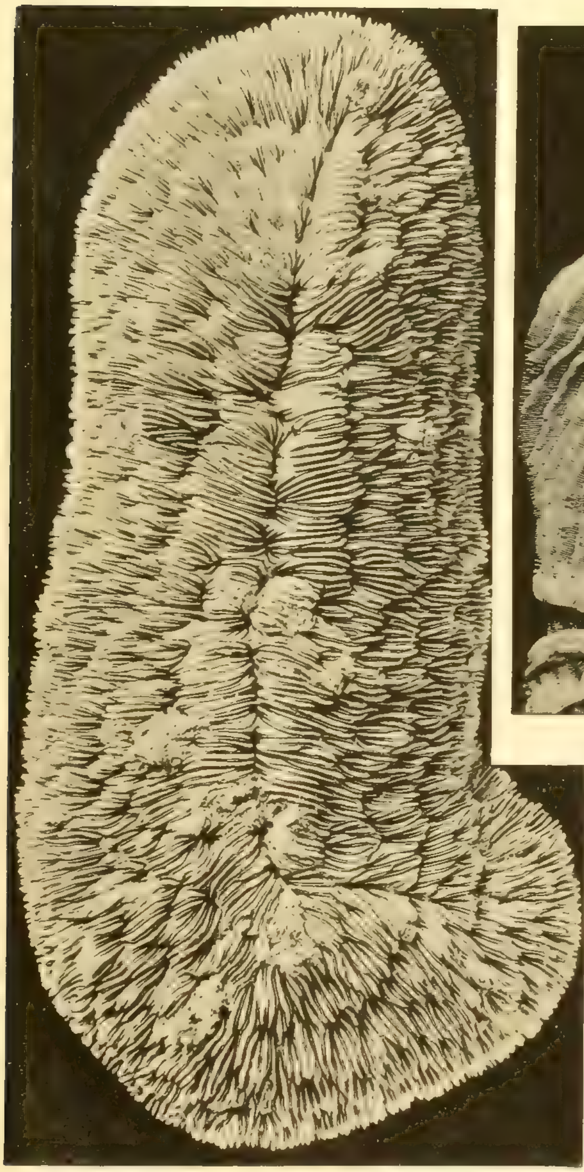


4

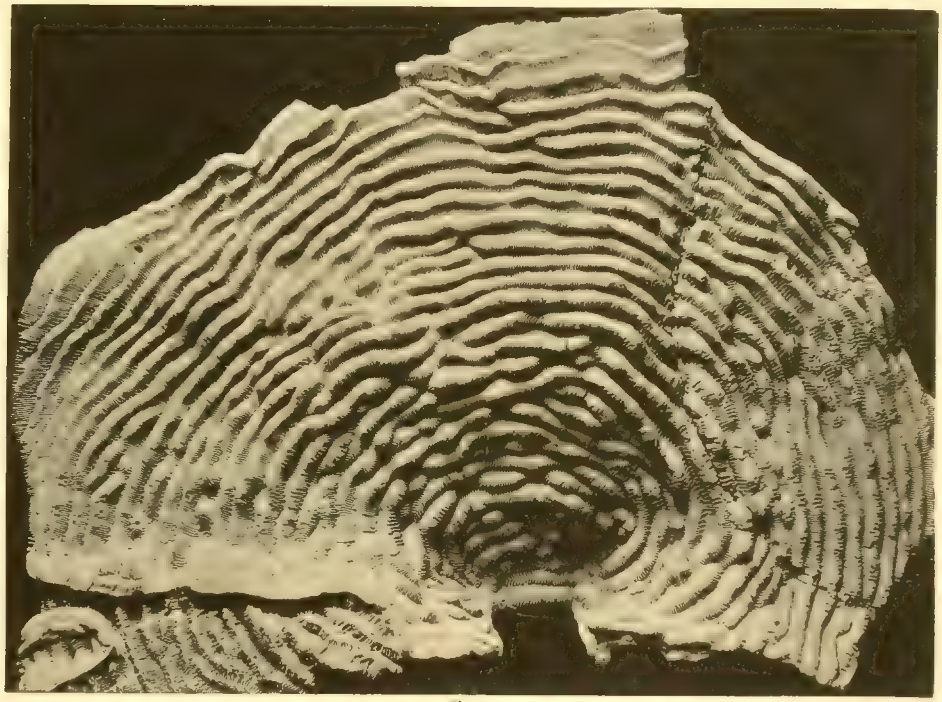
4a × 3



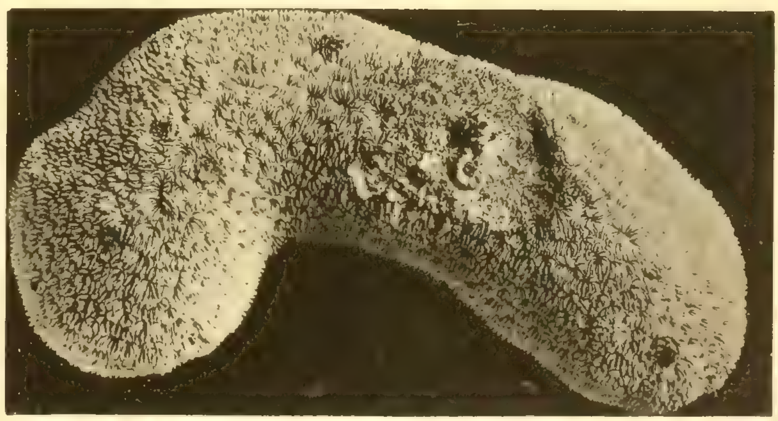
3a × 5



1 × ½

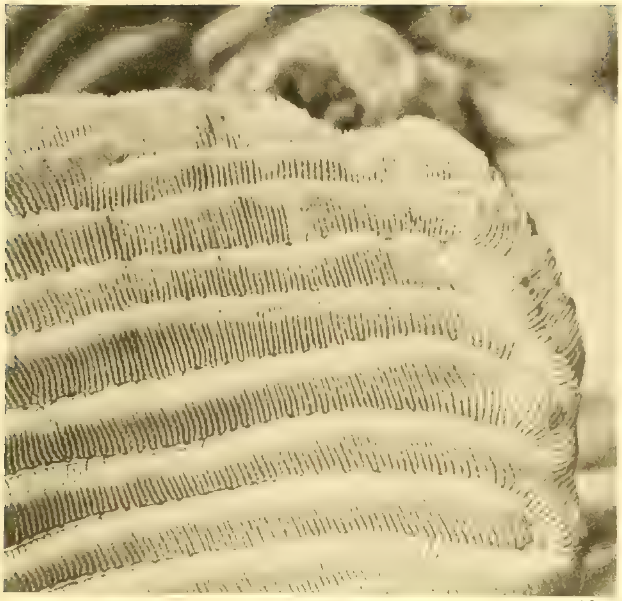


3

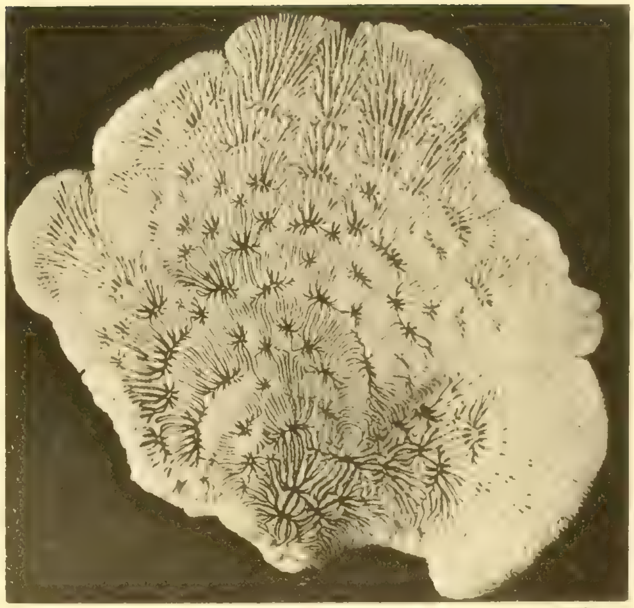


2 × ½

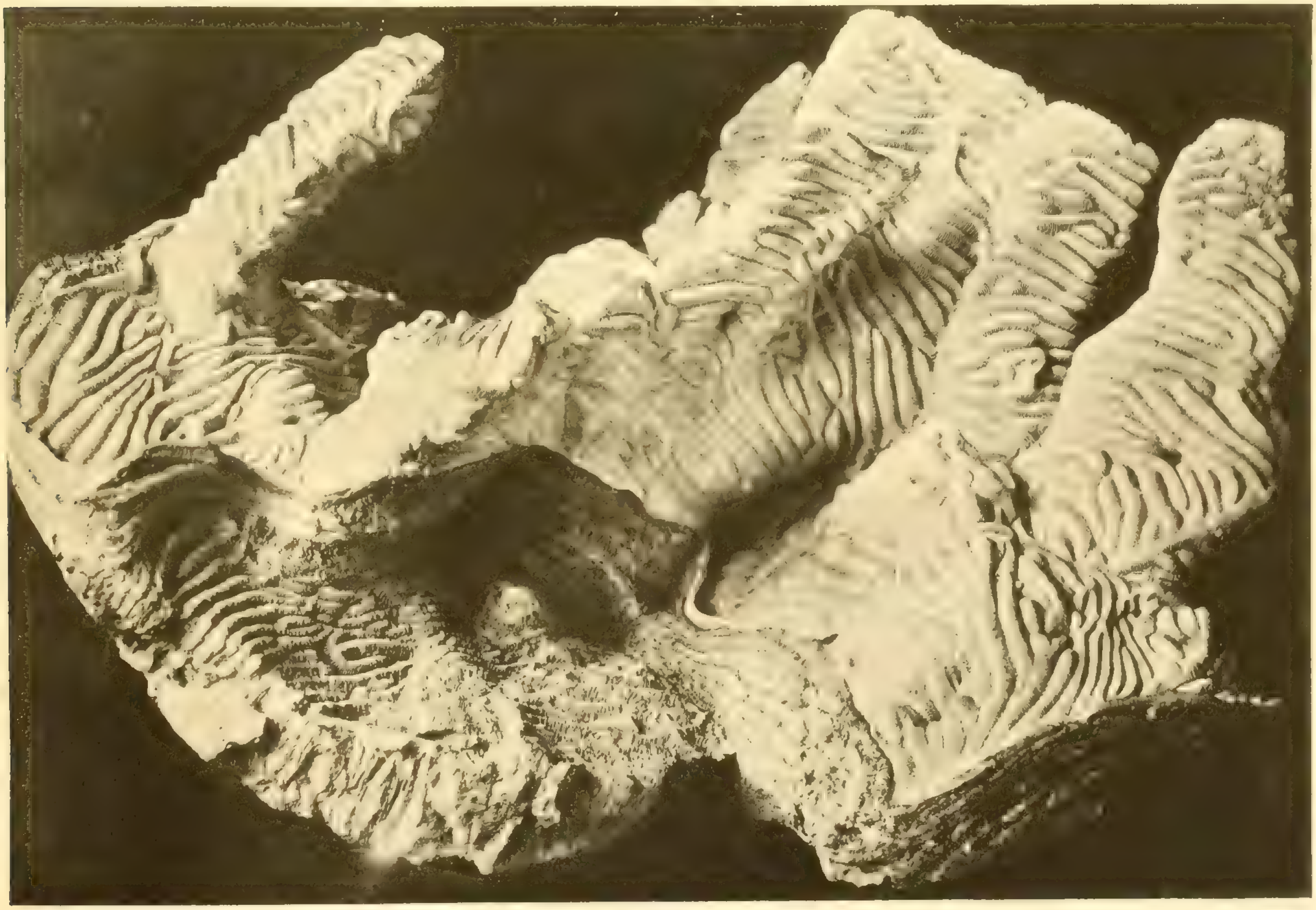
FIG. 1. *Herpetolitha crassa* Dana. FIG. 2. *Polyphyllia talpina* (Lam.).
FIGS. 3, 3*a*, 4, 4*a*. *Pachyseris speciosa* (Dana).



1a ×3

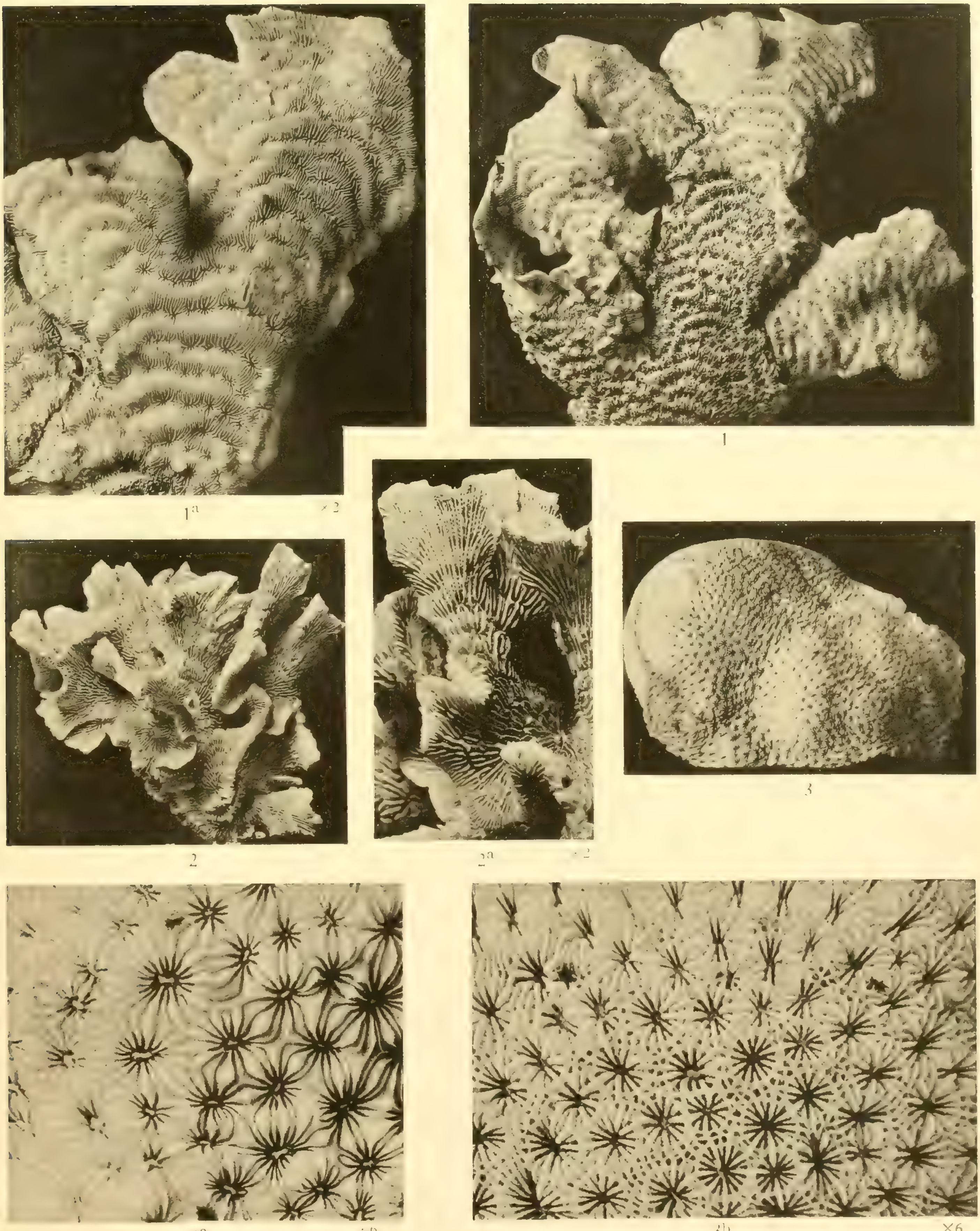


2 ×2

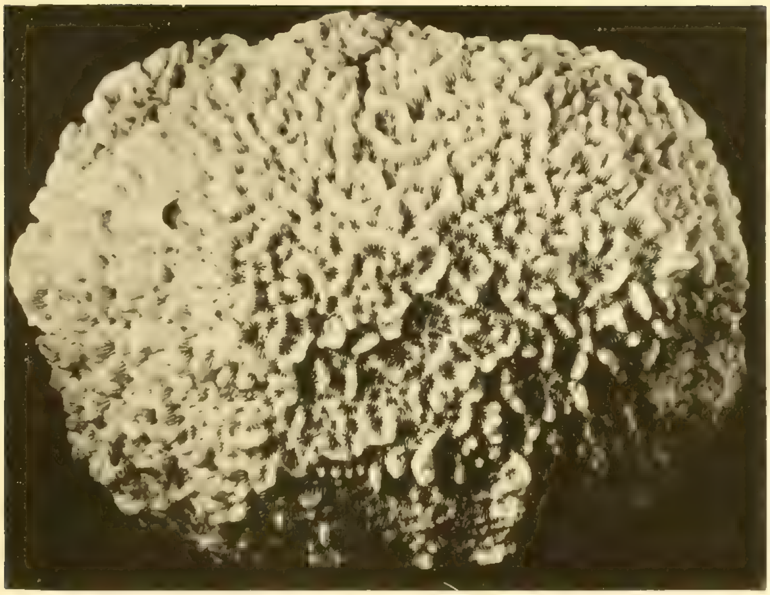


1

FIGS. 1, 1*a*. *Pachyseris torresiana*, new species. FIG. 2. *Pavona danai* (M. Edw. and H.).



Figs. 1, 1*a*. *Pavona cactus* (Forsk.). Figs. 2, 2*a*. *Pavona danai* (M. Edw.).
Figs. 3, 3*a*, 3*b*. *Pavona maldivensis* (Gardiner).



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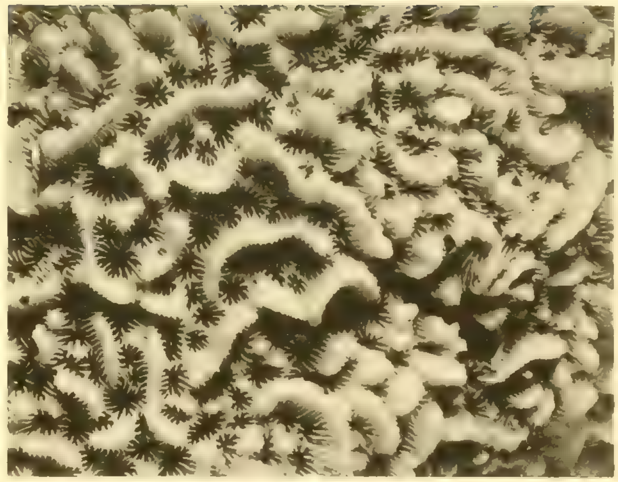
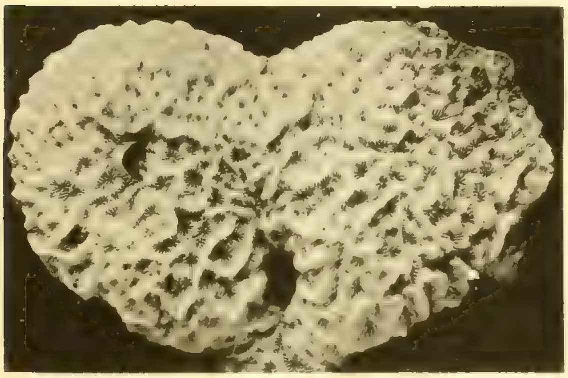


4a ×4



2

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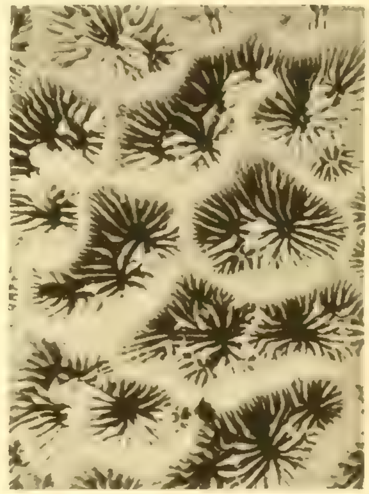
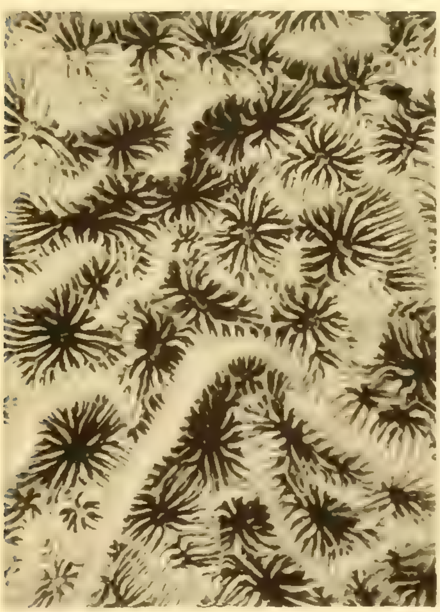
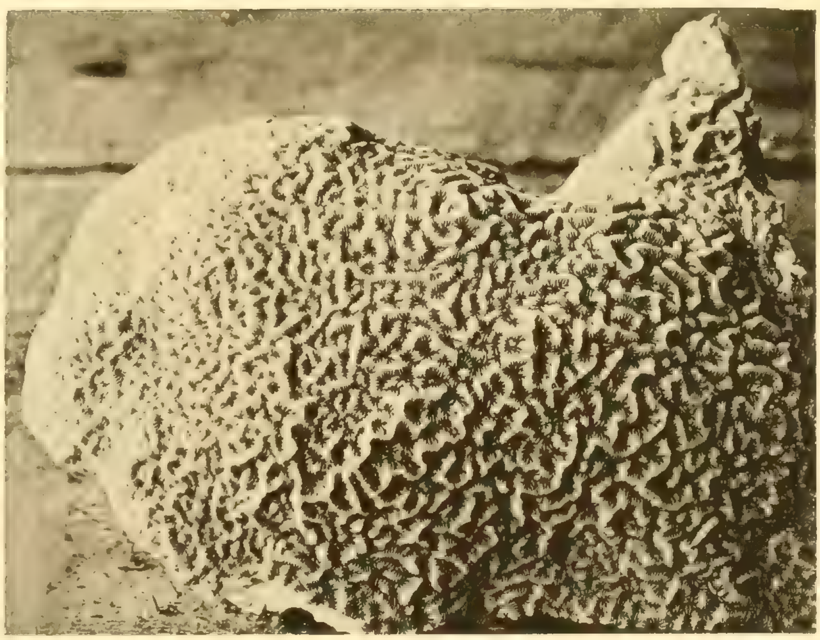


1a ×4

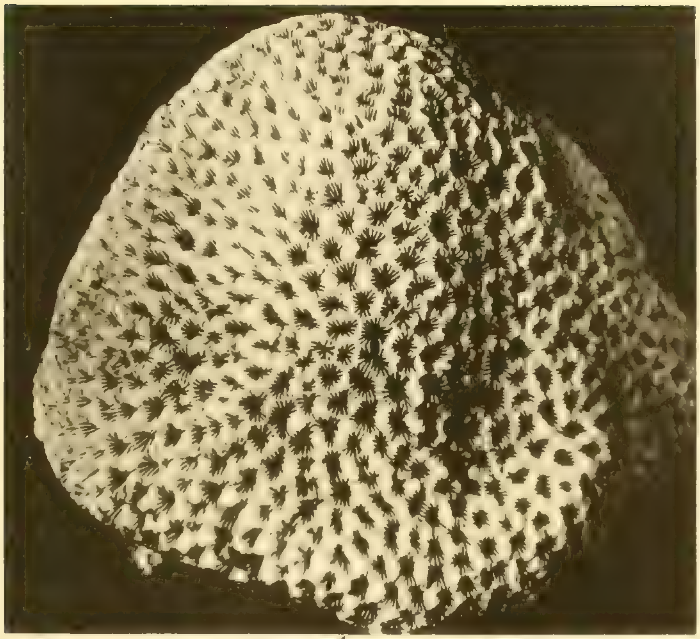


2a ×4



3

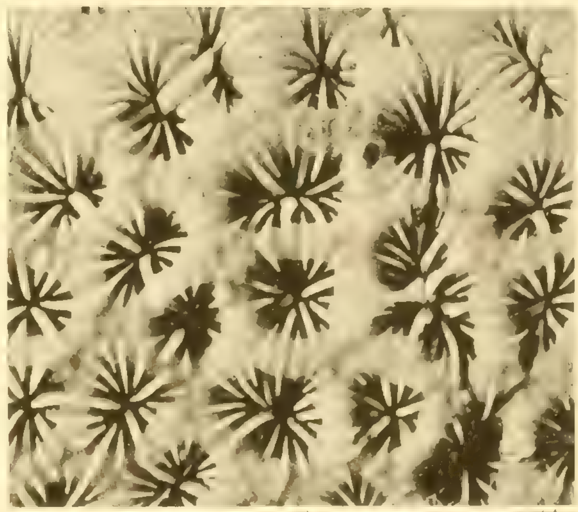
Pavona varians Verrill.



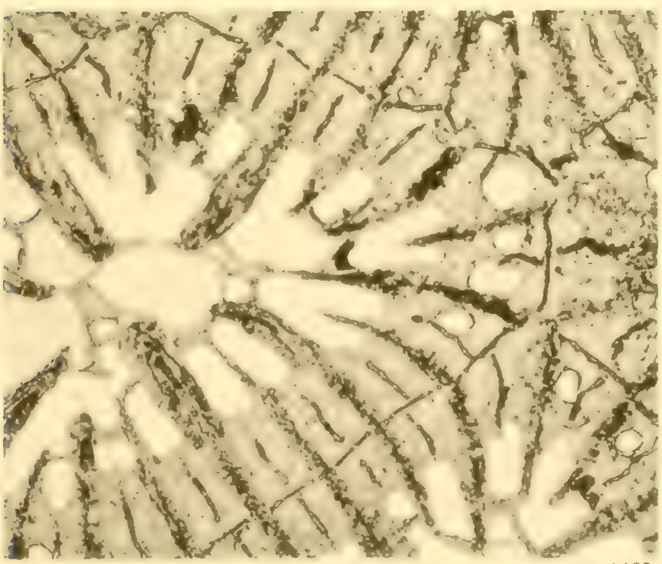
1

2 ×4

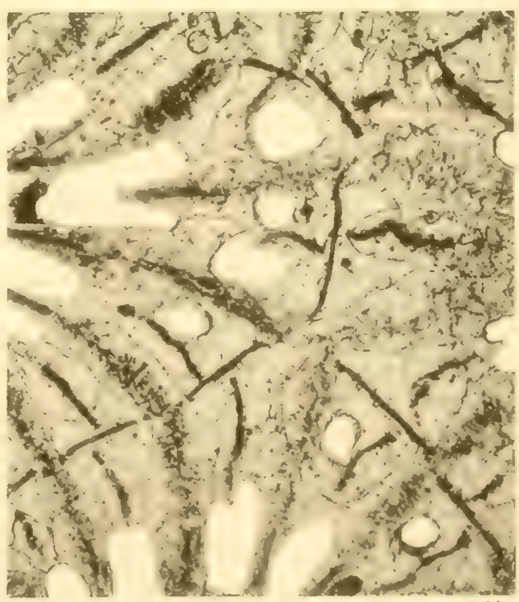
1a ×4



1b ×4

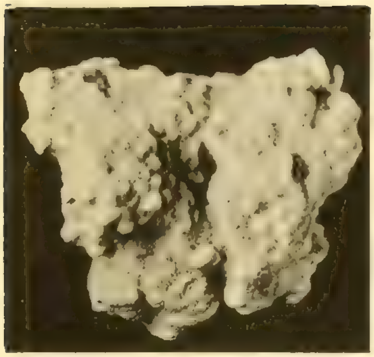


3 ×20



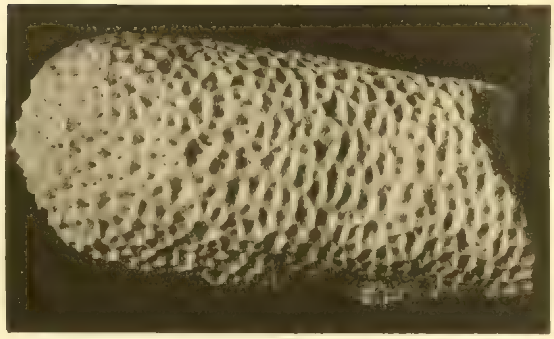
3a ×30

Coeloseris mayeri, new gen. and sp.



3

1 ×6



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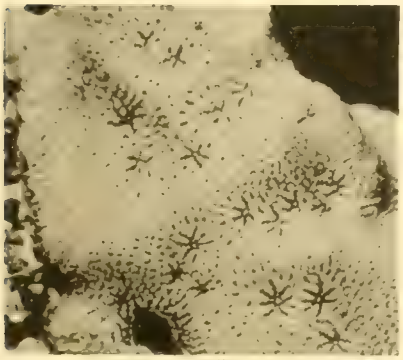
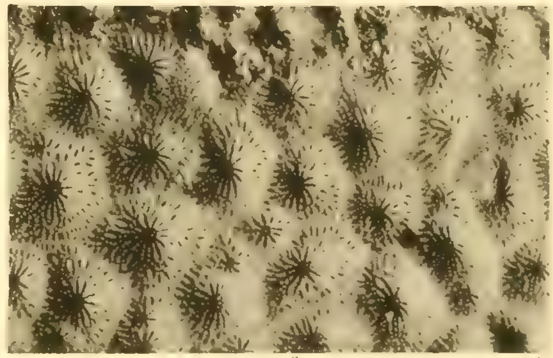
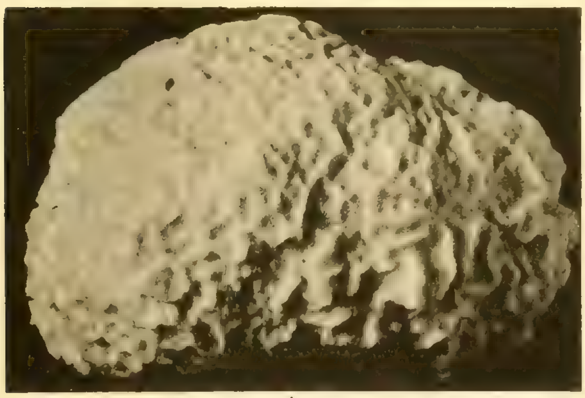


3a ×6



2a ×4



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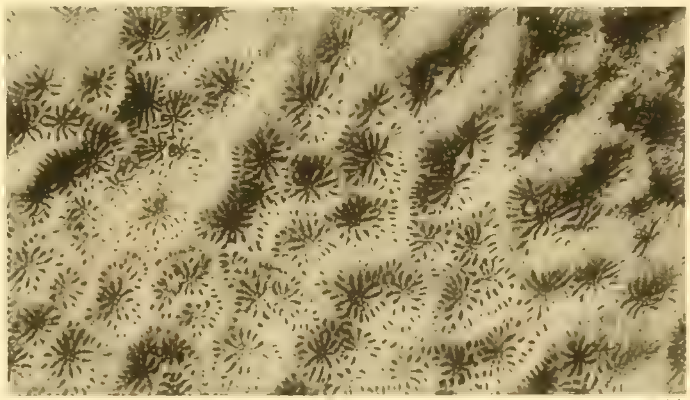
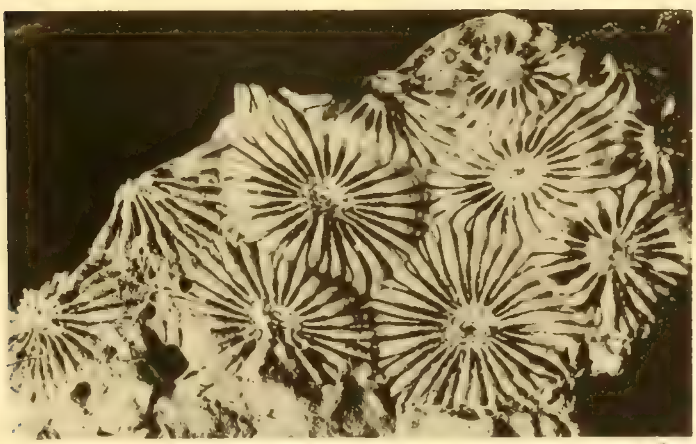
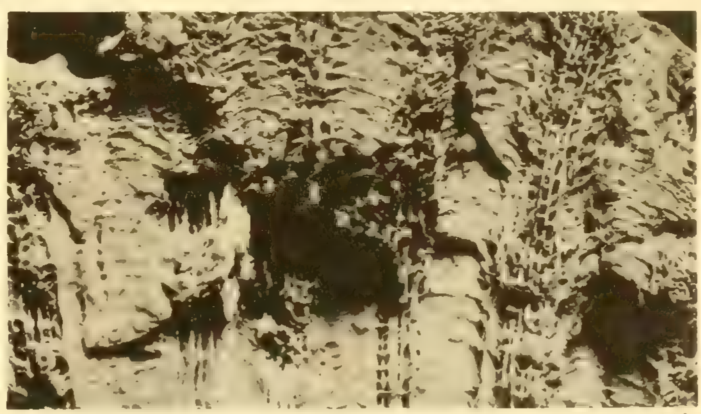


4a ×4

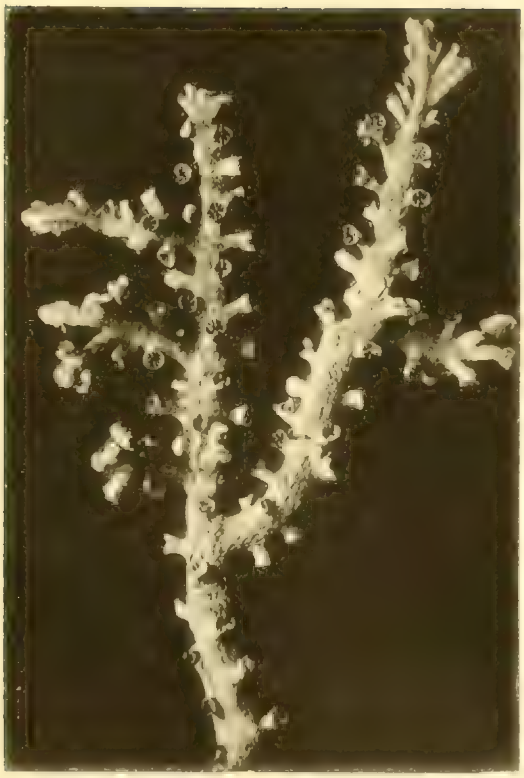


5 ×2



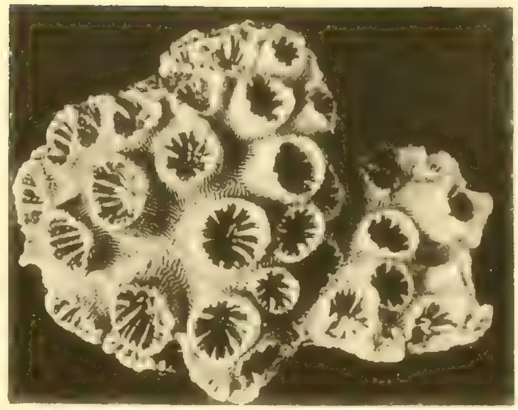
5a ×2

FIG. 1. *Psammocora gonagra* Klz. FIGS. 2, 2*a*. *Psammocora haimiana* M. Edw. and H. FIGS. 3, 3*a*. *Psammocora* sp.
FIGS. 4, 4*a*. *Psammocora profundacella* Gardiner. FIGS. 5, 5*a*. *Diploastrea heliopora* (Lam.).



1 ×½

1a ×4



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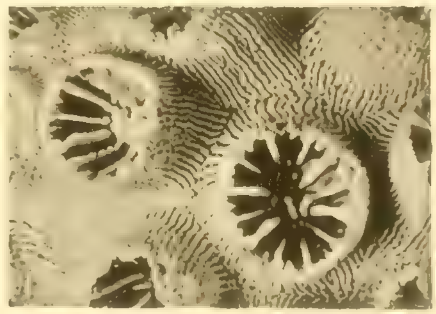
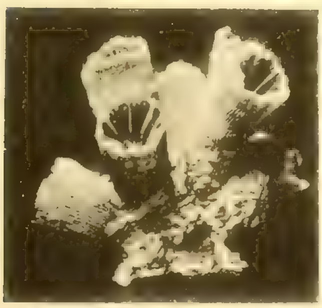


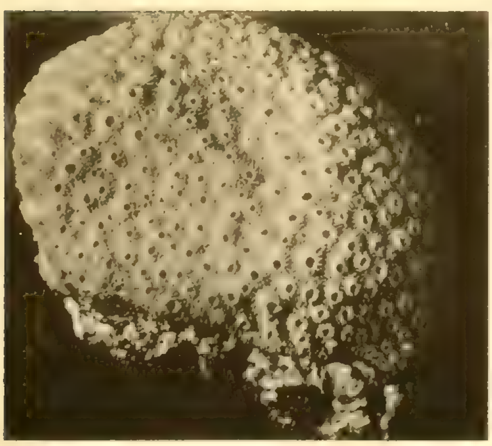
4a ×2



3

2a ×2

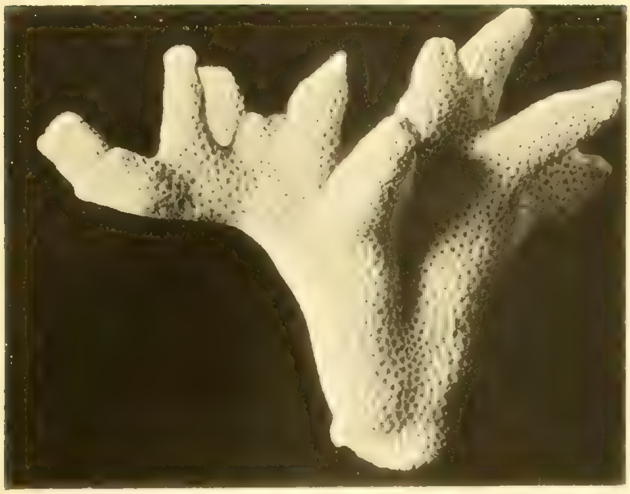
3a ×2



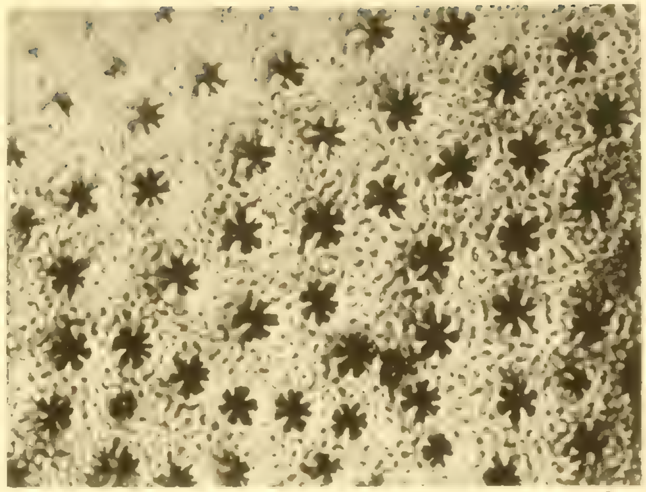
5

5a ×4

Figs. 1, 1*a*. *Dendrophyllia nigrescens* Dana. Figs. 2, 2*a*, 3, 3*a*. *Dendrophyllia diaphana* Dana.
Figs. 4, 4*a*. *Dendrophyllia willeyi* (Gardiner). Figs. 5, 5*a*. *Astreopora myriophthalma* (Lam.).

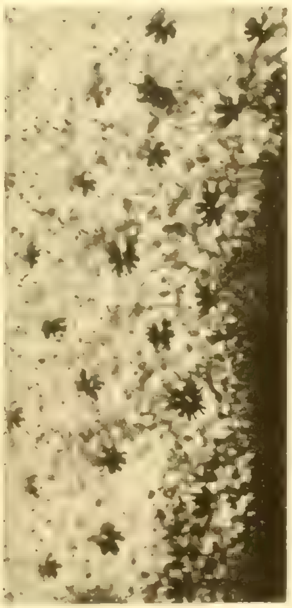


1

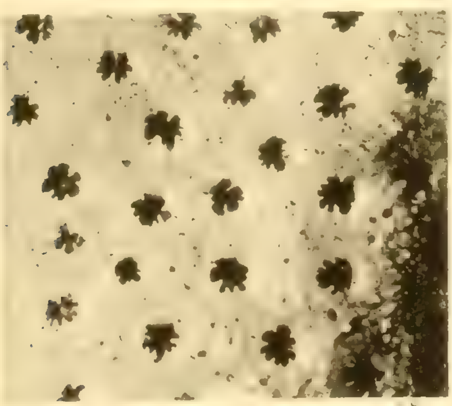


1a ×8

3



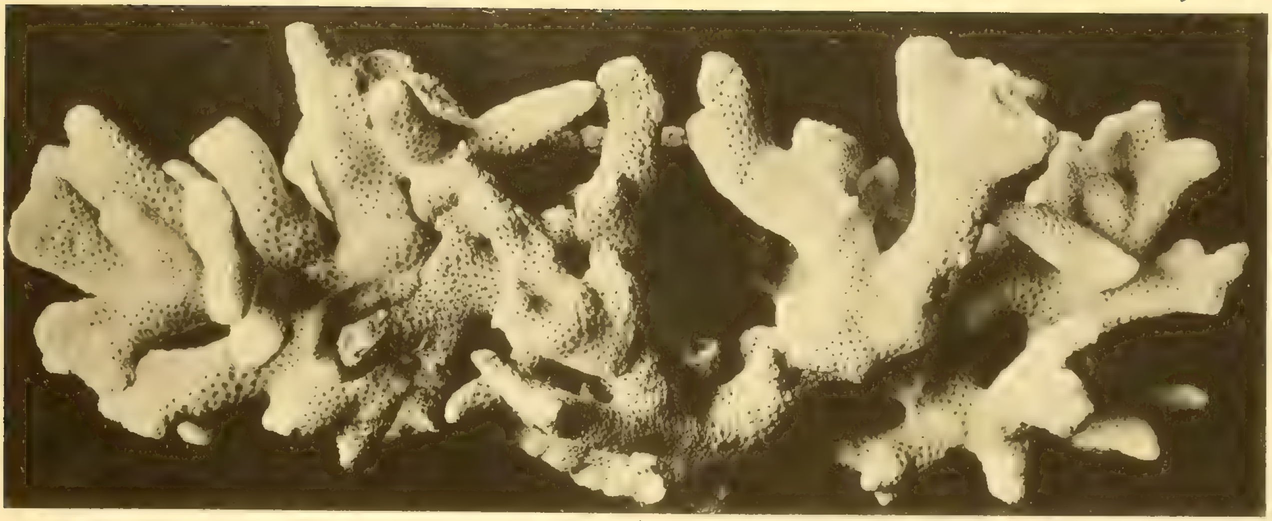
3a ×8



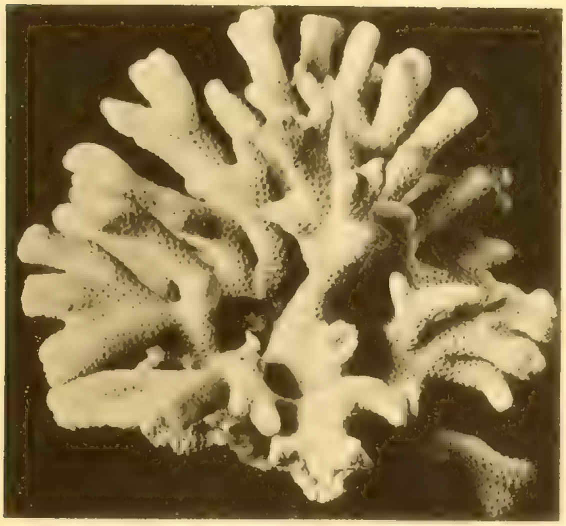
2a ×8

2

FIGS. 1, 1*a*. *Montipora levis* Quelch. FIGS. 2, 2*a*, 3, 3*a*. *Montipora tortuosa* (Dana).



1



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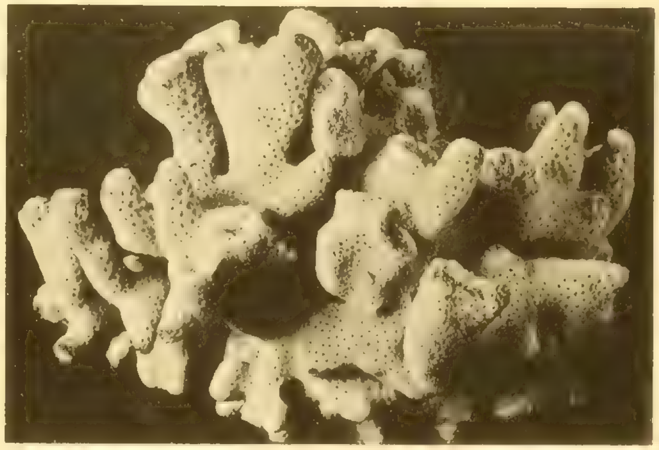


3

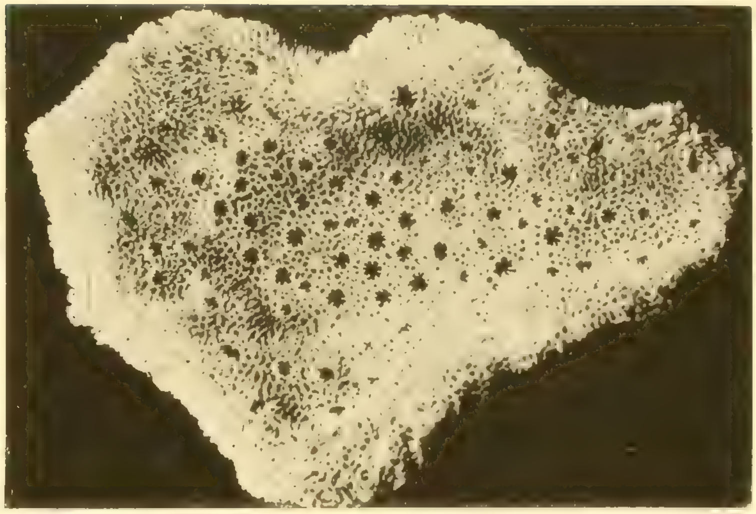
1a ×8

4a ×8

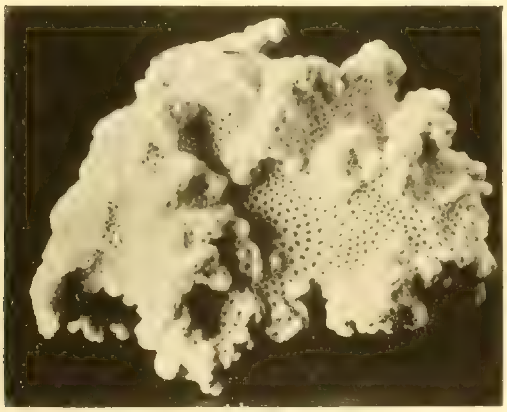
4

Figs. 1, 1*a*, 2, 3. *Montipora ramosa* Bernard. Figs. 4, 4*a*. *Montipora turgescens* Bernard.

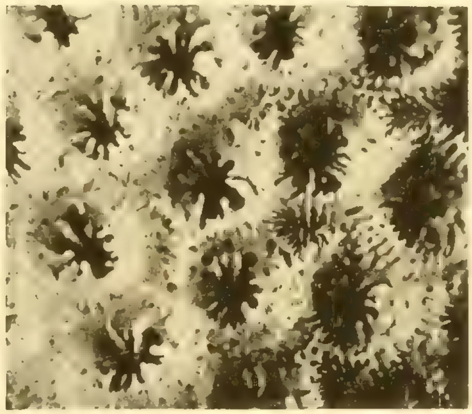
1



1a ×3

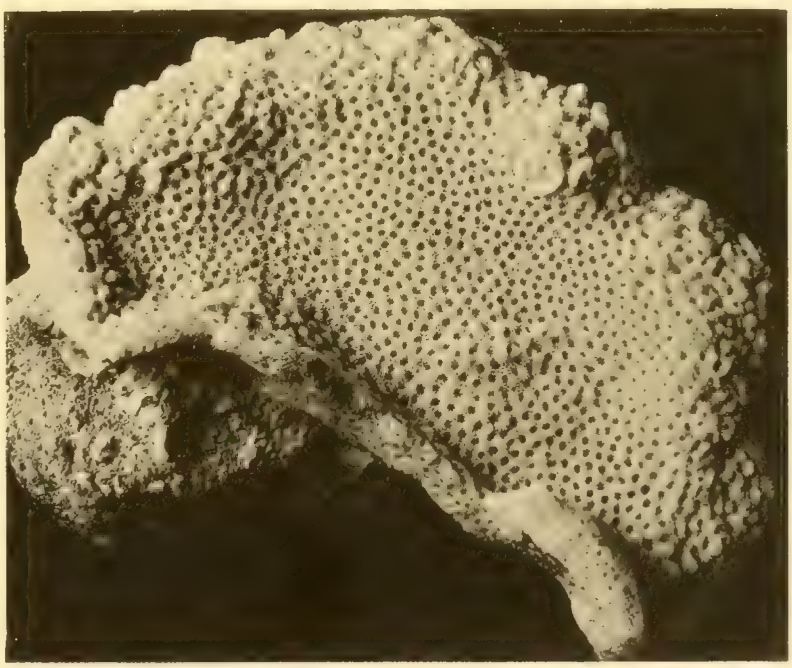


2



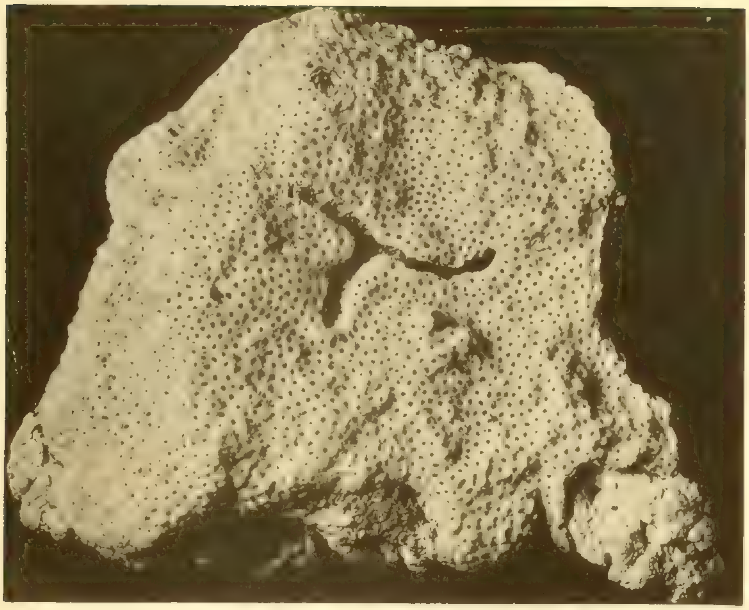
1b ×8

2a

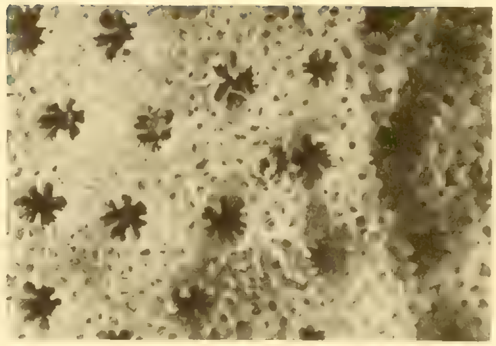


3

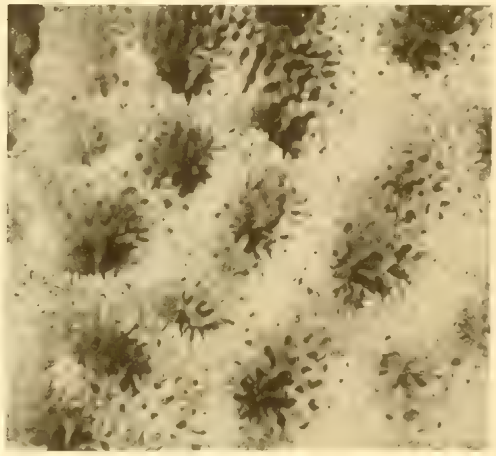
FIGS. 1, 1*a*, 1*b*. *Montipora cocosensis* new species. FIGS. 2, 2*a*. *Montipora spumoso* (Lam.).
FIG. 3. *Montipora venosa* (Ehrenberg).



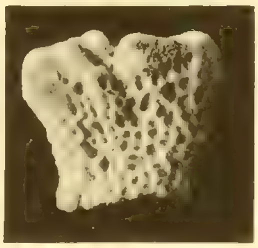
1



1a ×8

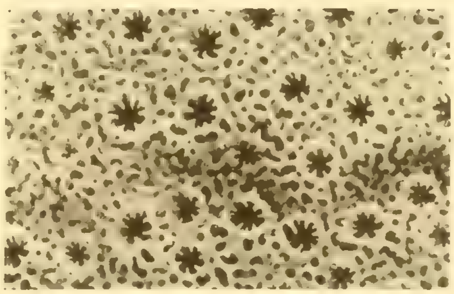


2a ×8

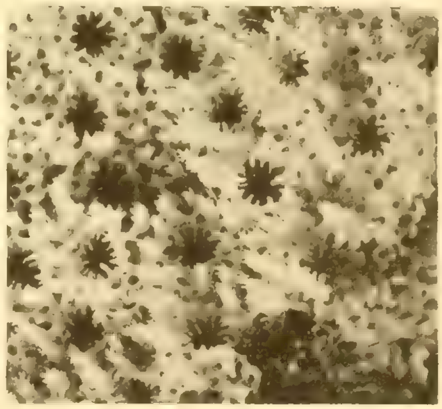


2

3



4c ×8



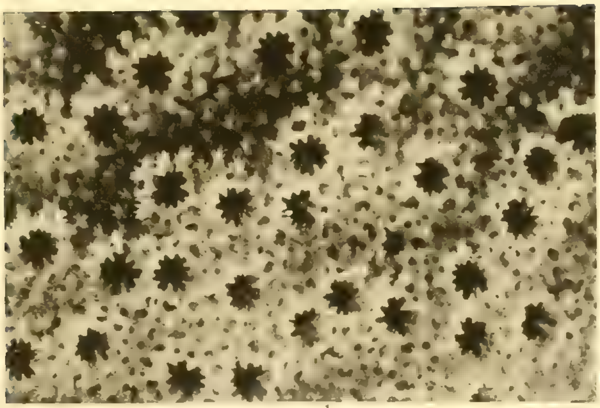
4b ×8

4a

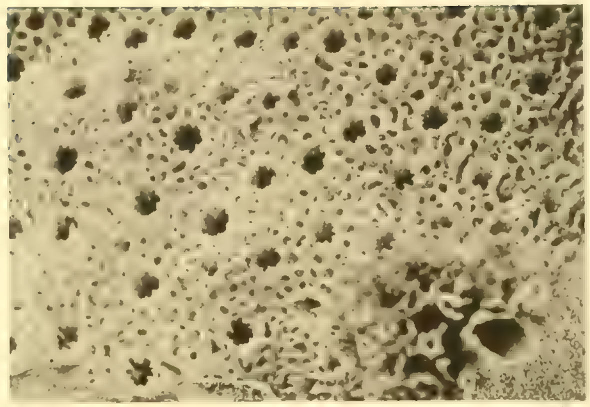
4

FIGS. 1, 1*a*. *Montipora elschneri*, new species. FIGS. 2, 2*a*. *Montipora* sp.

FIGS. 3, 4, 4*a*, 4*b*, 4*c*. *Montipora informis* Bernard.



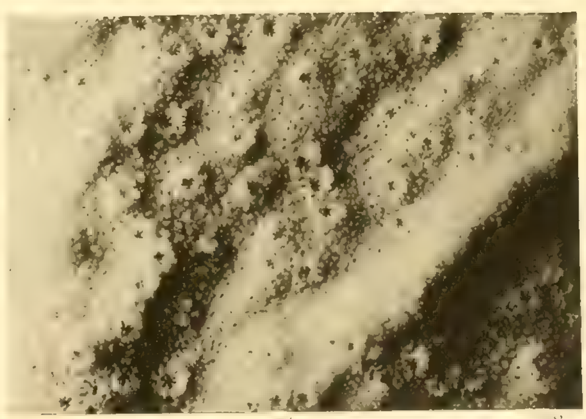
1 ×8



1a ×8

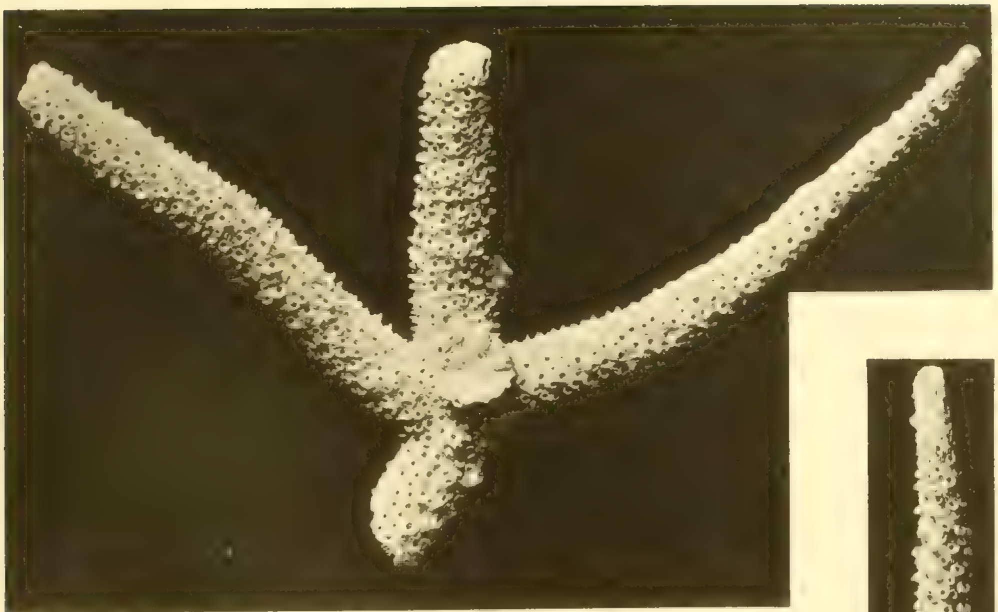
2

2a ×8

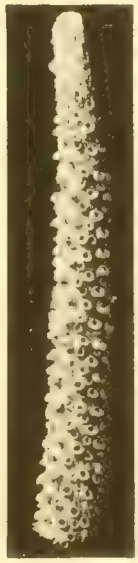


2b ×8

FIGS. 1, 1*a*. *Montipora* aff. *M. informis* Bernard. FIGS. 2, 2*a*, 2*b*. *Montipora foliosa* (Pall.).



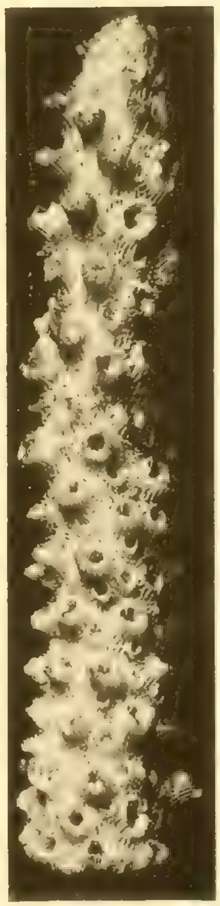
1



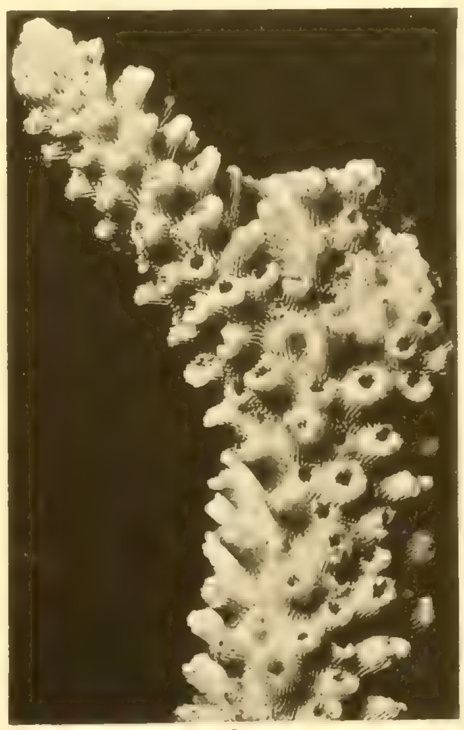
3

3a ×3

4



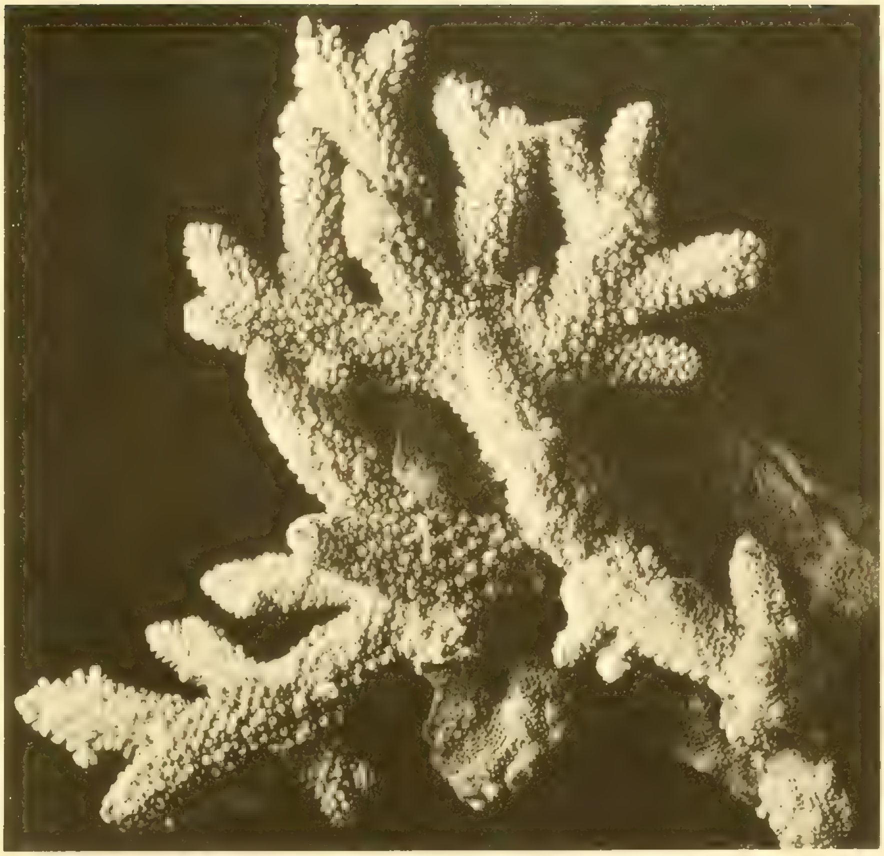
2 ×3



5 ×3

FIGS. 1, 2. *Acropora pulchra* var. *alveolata* (Brook). FIGS. 3, 3*a*. *Acropora pulchra* (Brook).
FIGS. 4, 5. *Acropora haimei* (M. Edw.) var.

1

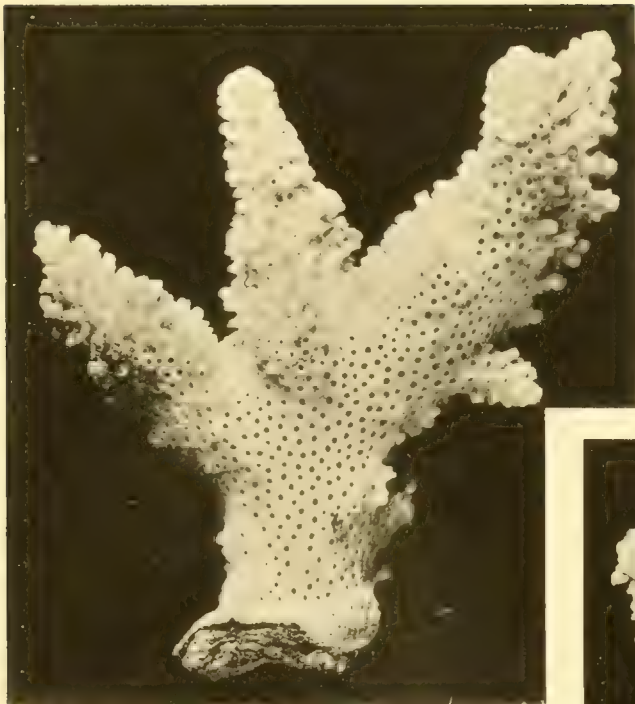


2 × ½

2^a

2^b

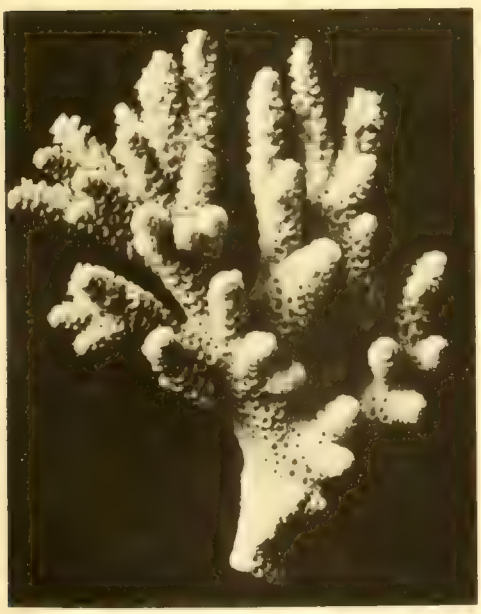
FIG. 1. *Acropora corymbosa* (Lam.). FIGS. 2, 2*a*, 2*b*. *Acropora decipiens* (Brook).



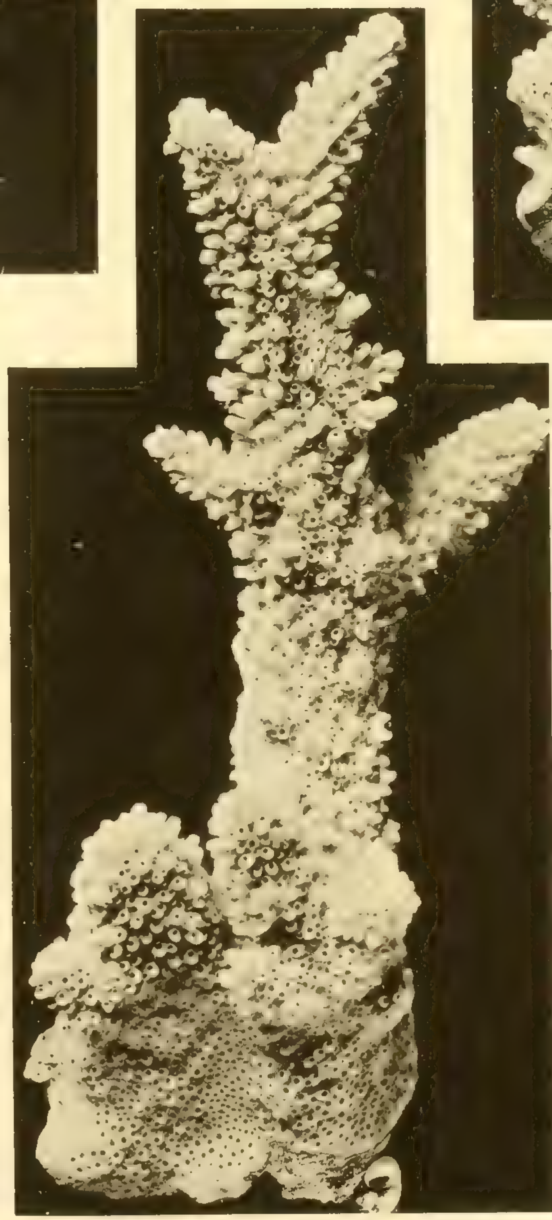
1

1a

3a ×5



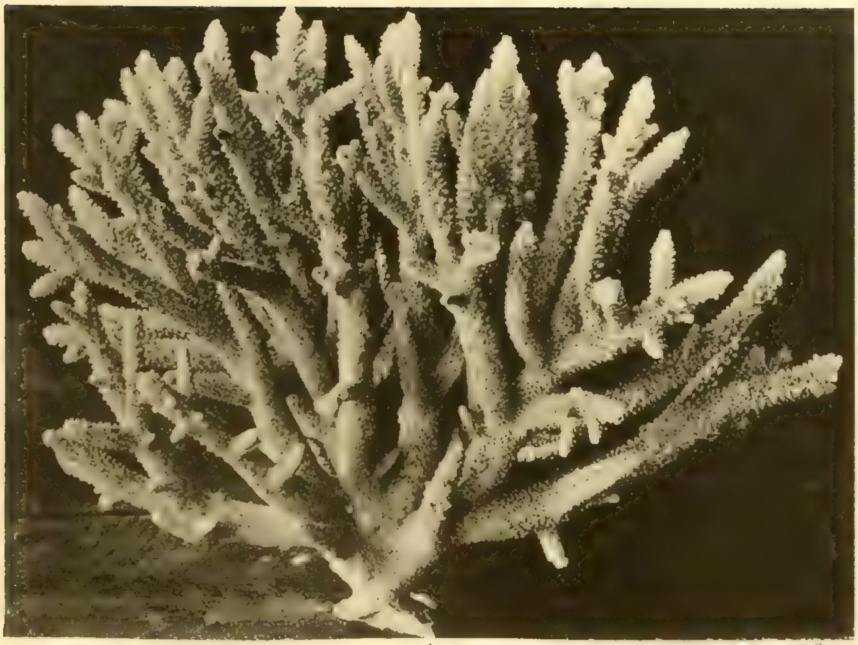
3



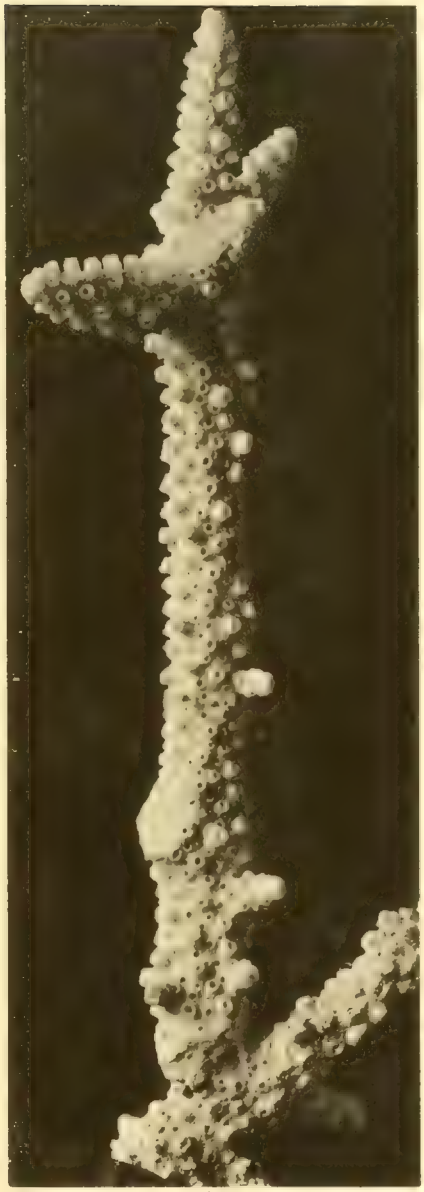
2

3a

FIGS. 1, 1*a*, 2. *Acropora abrotanoides* (Lam.). FIGS. 3, 3*a*, 3*b*. *Acropora spicifera* (Dana).



1



2

3a

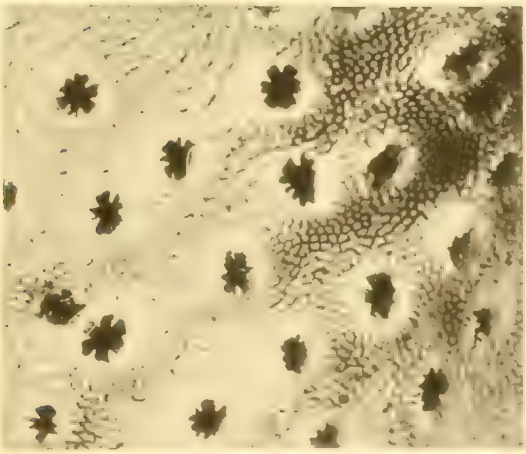
4

4a

5

1 ×2/7

2



2a ×8

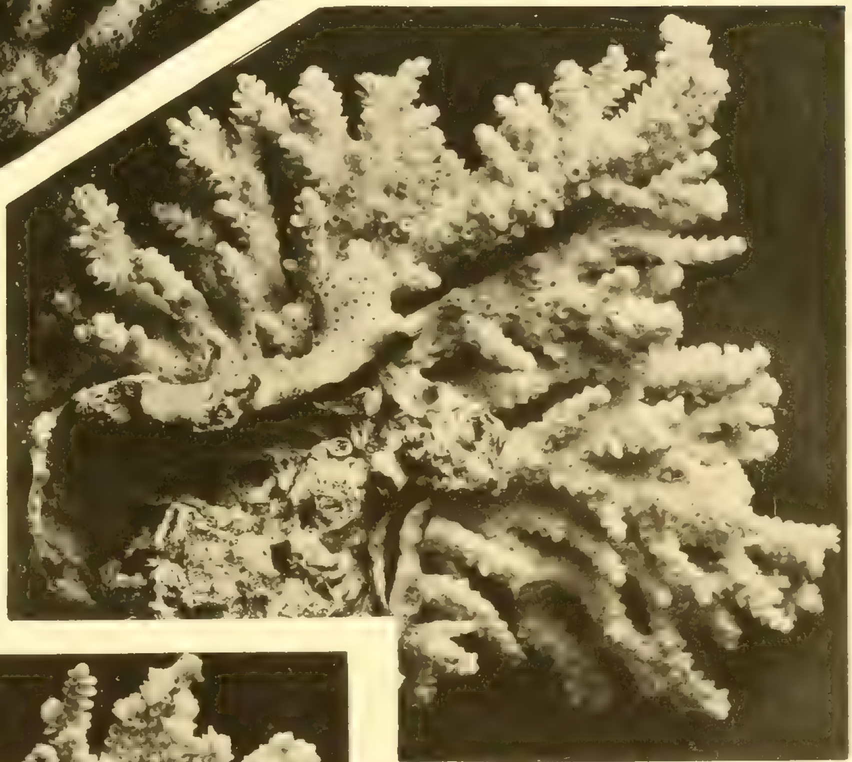
3a ×3

3b ×3

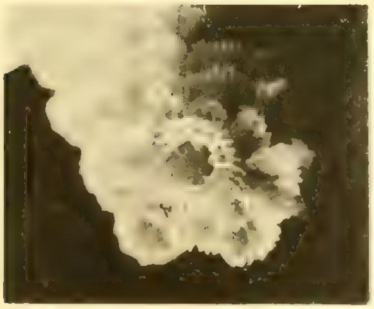
3 ×1/2

FIG. 1. *Acropora pharaonis* (M. Edw.). FIGS. 2, 2*a*. *Acropora pharaonis* forma *arabica* (M. Edw.).
FIGS. 3, 3*a*, 3*b*. *Acropora haimei* (M. Edw.).

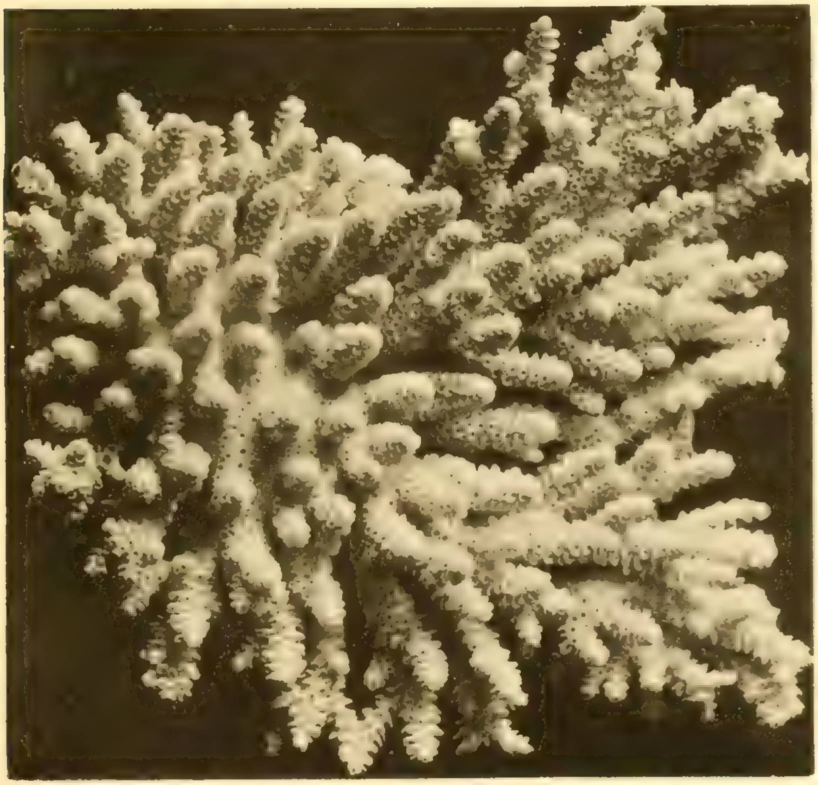
2



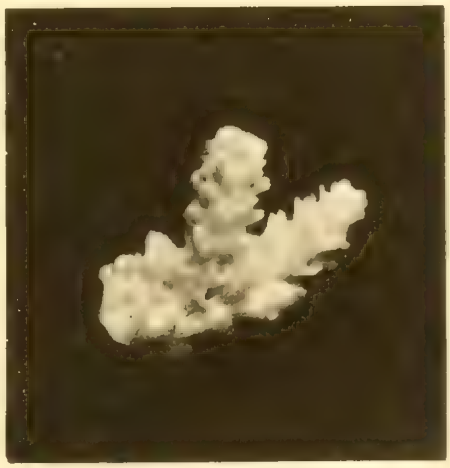
1^a^



1^c^ ×8

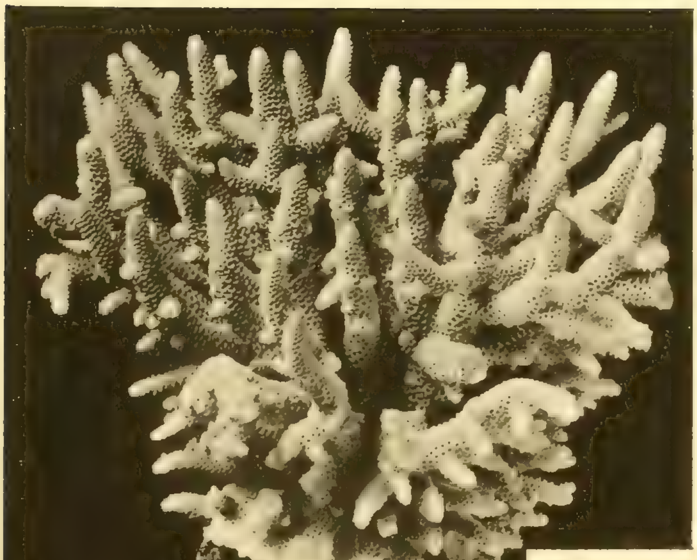


1

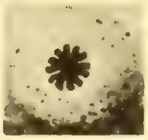


1^b^ ×3

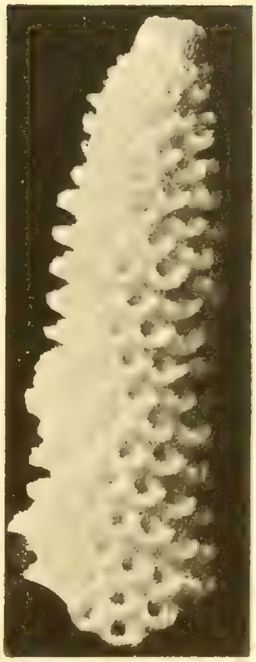
Acropora pectinata (Brook).



1 ×½

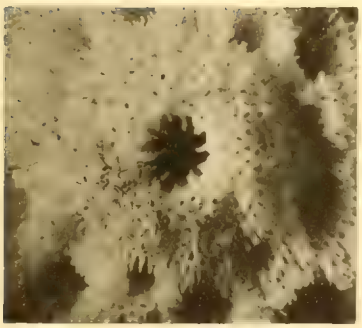


2a ×3

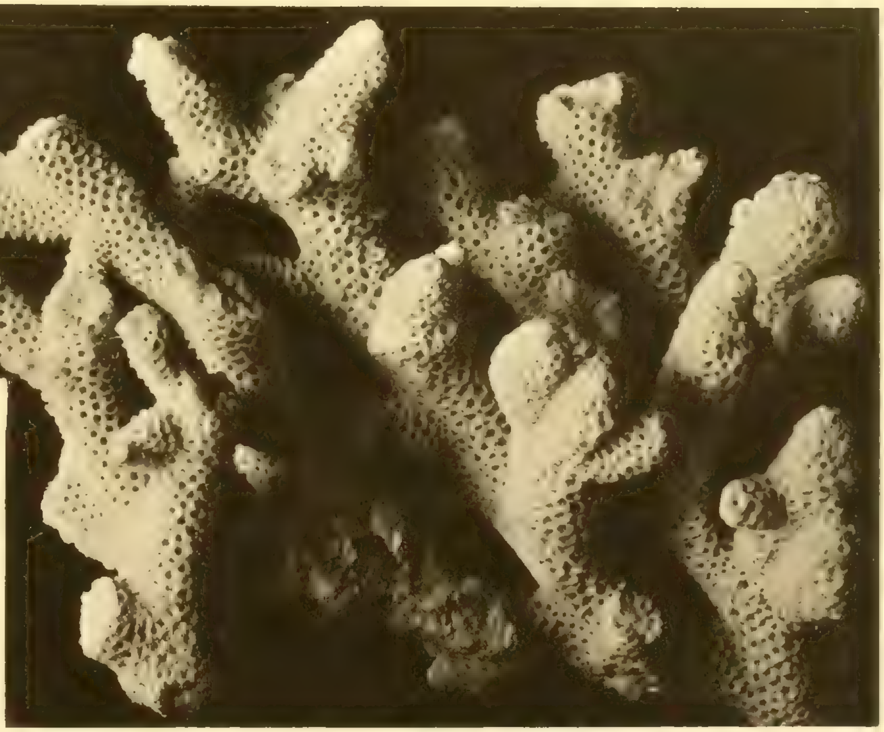


2 ×3

3

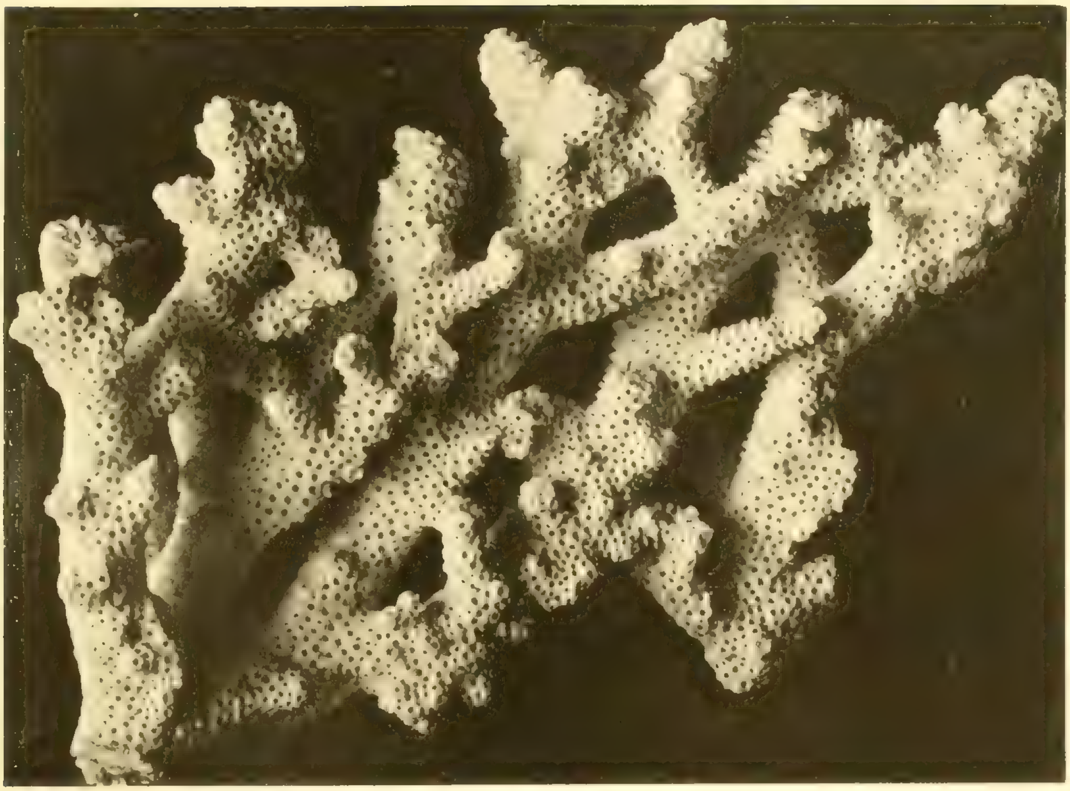


4a ×8



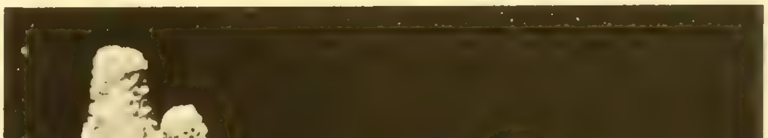
4

FIGS. 1, 2, 2*a*, 3. *Acropora squamosa* (Brook). FIGS. 4, 4*a*. *Acropora sarmentosa* (Brook).



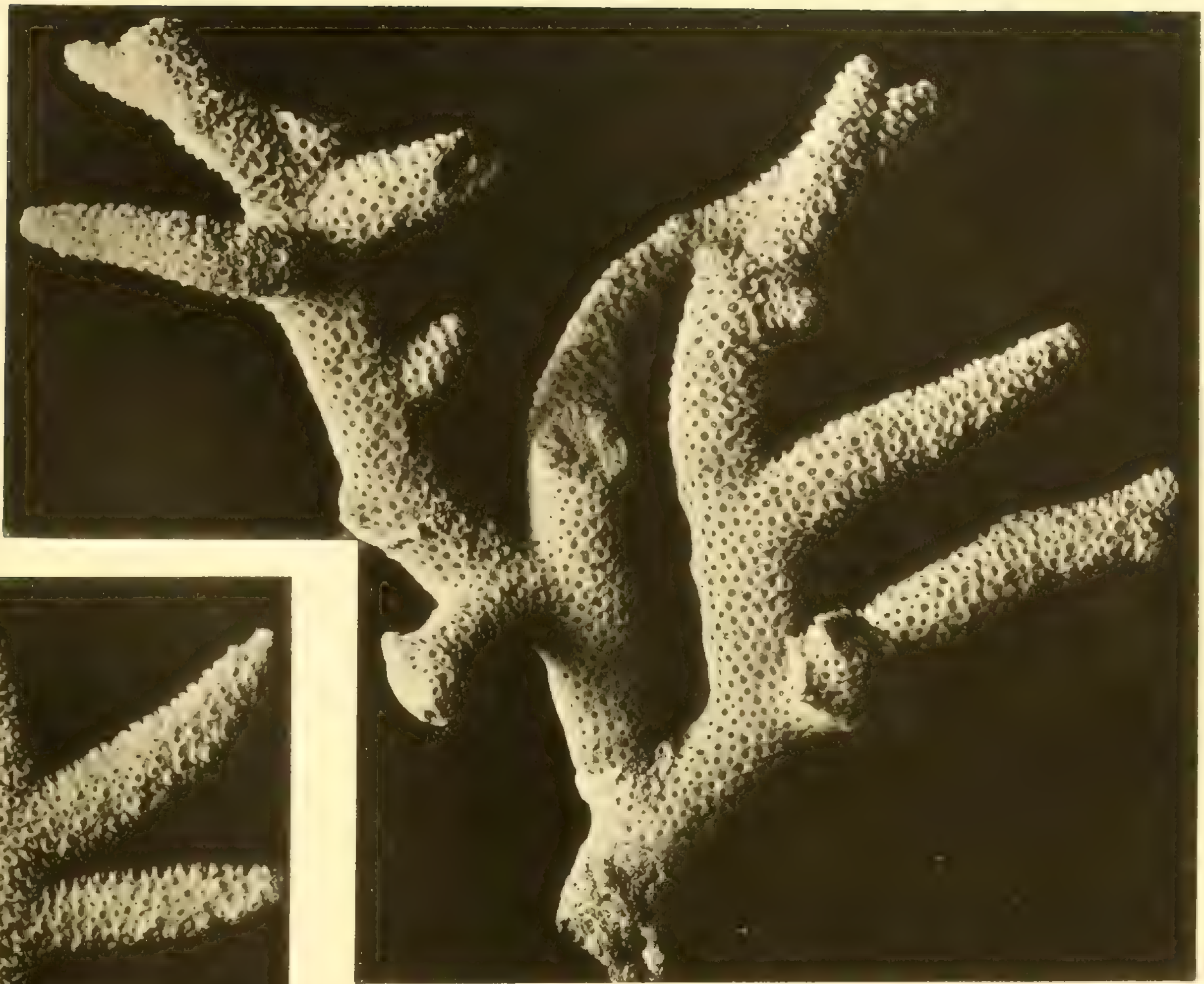
1

2a ×3

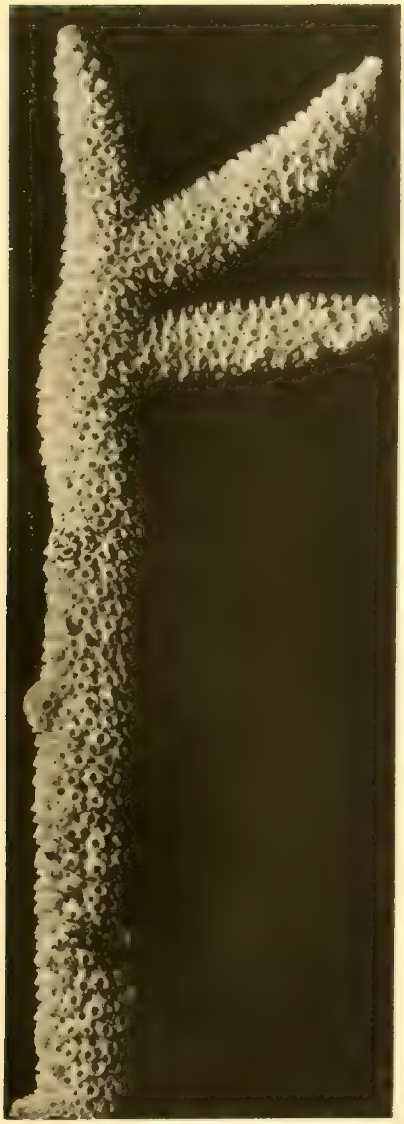


2

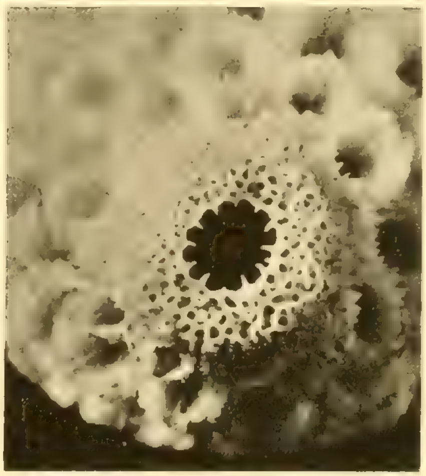
FIG. 1. *Acropora sarmentosa* (Brook). FIGS. 2, 2*a*. *Acropora hebes* (Dana).



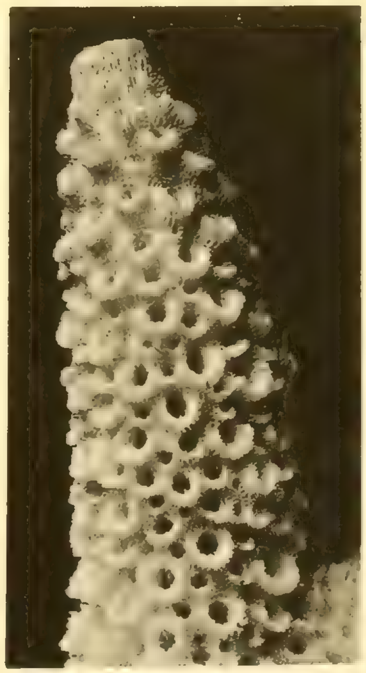
1



2



2b ×8



2a ×5

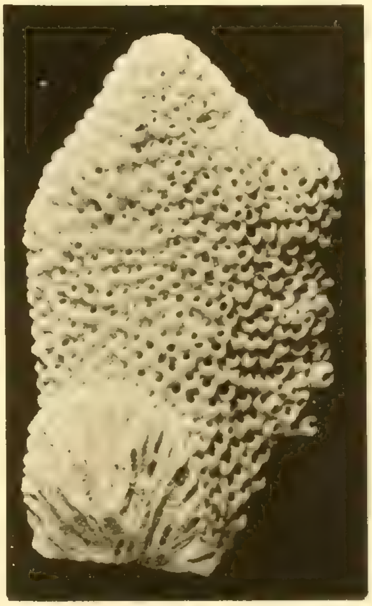
Acropora hebes (Dana).

2

2^{b} $\times 3$

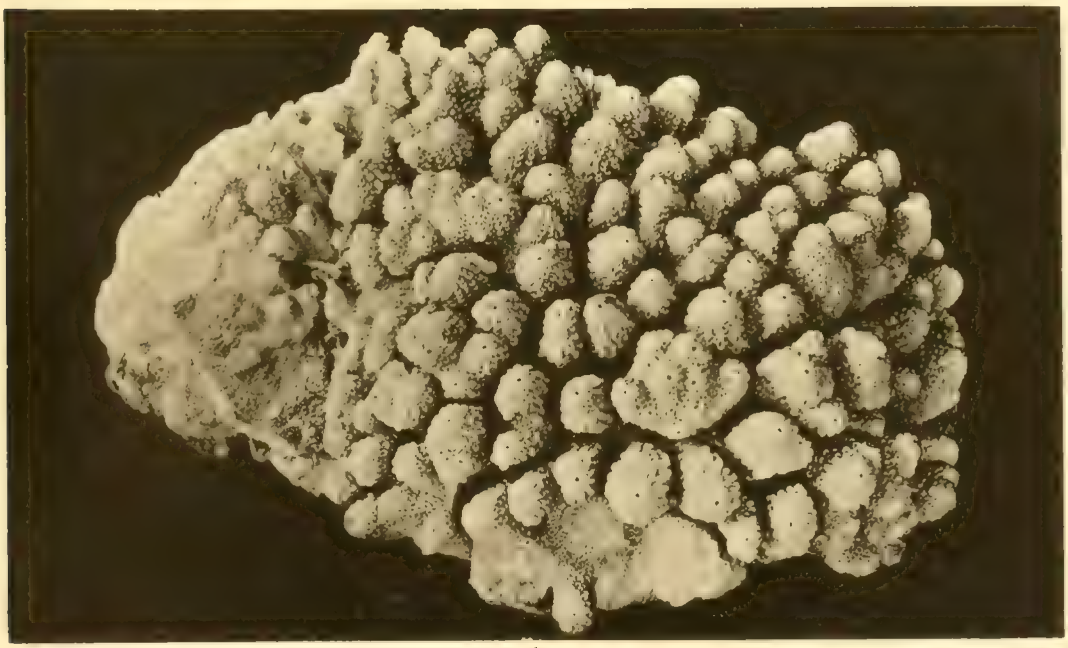
3^{a}

2^{a}



3

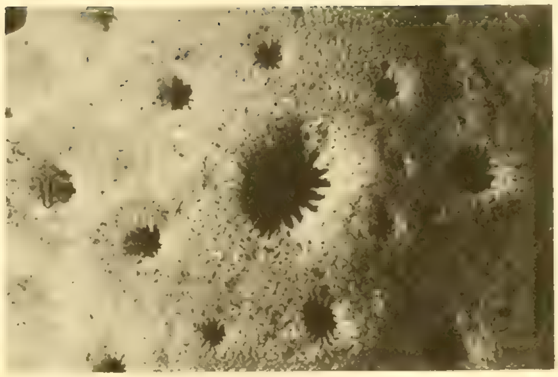
4



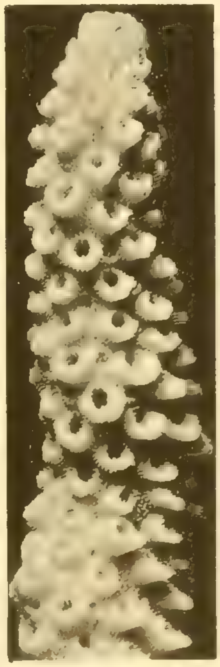
1 $\times \frac{2}{3}$

Acropora scherzeriana (Brueg.).

3a ×3

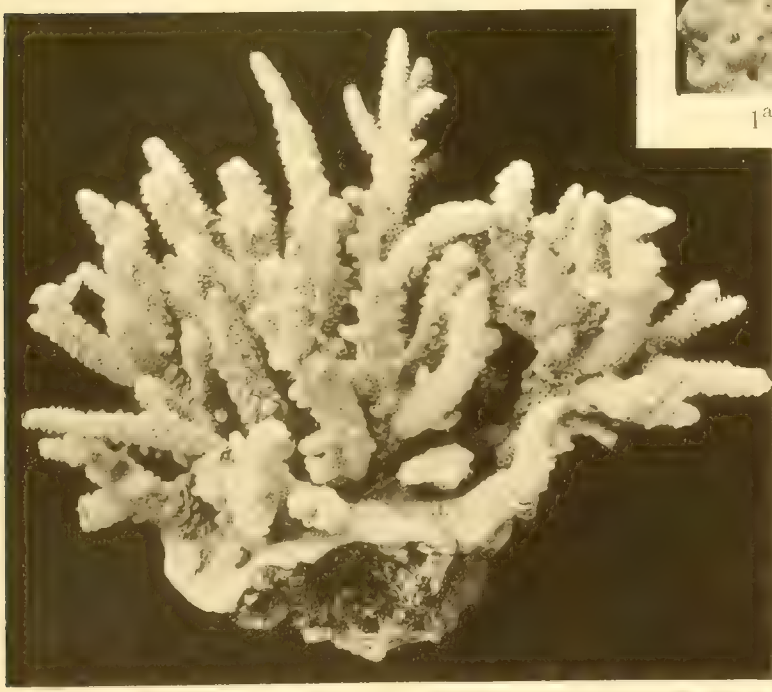


3b ×8



1a

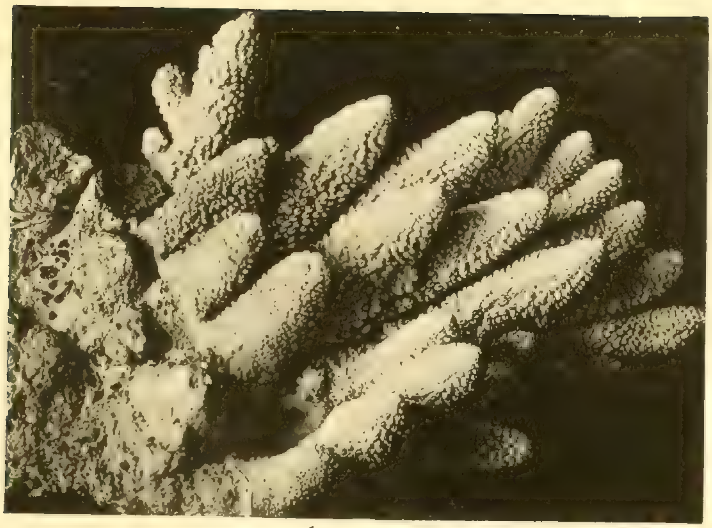
2



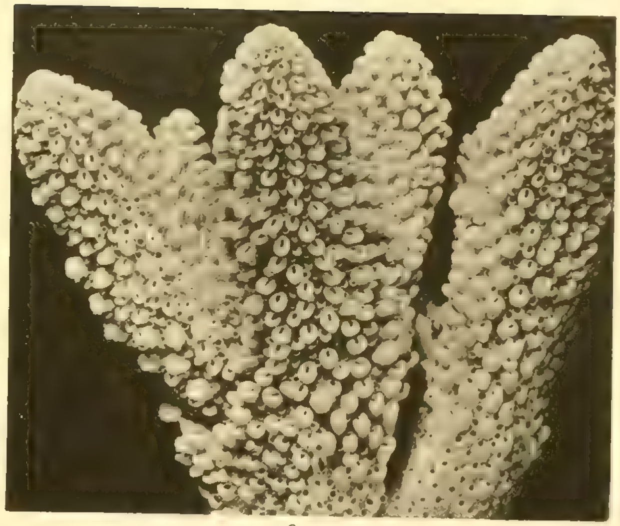
1 ×½

3

FIGS. 1, 1*a*, 2. *Acropora digitifera* (Dana). FIGS. 3, 3*a*, 3*b*. *Acropora ocellata* (Klunzinger) var.



1 × 1/3



1a

2 × 1/3

2a

3 × 1/3

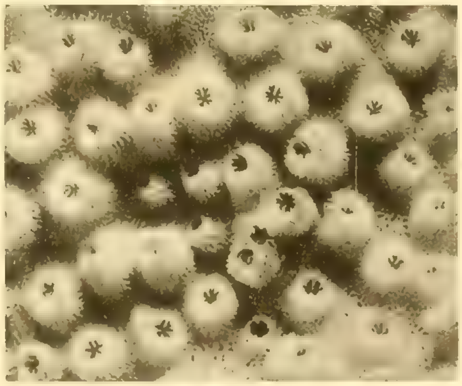
3a

Acropora gemmifera (Brook).

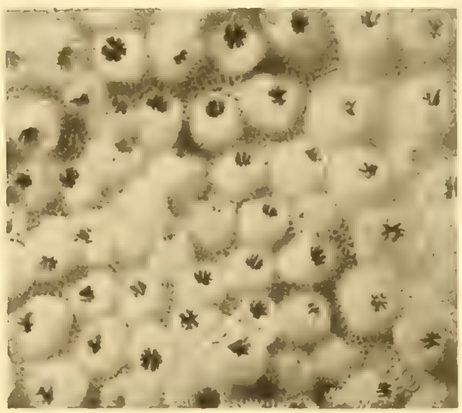
1

1^a ×4

1^b ×4



1^c ×4

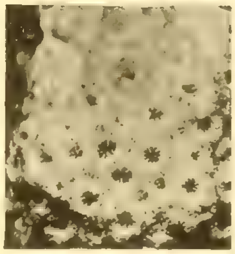


1^d ×4

Acropora palifera (Lam.).

1

2 × ½



4b × 2

4 × 2

4a × 2

3 × ½

FIG. 1. *Acropora palifera* (Lam.). FIGS. 2, 3, 4, 4*a*, 4*b*. *Acropora palifera* var. α (Brook).

1 × ½

1b ×2

1a ×2

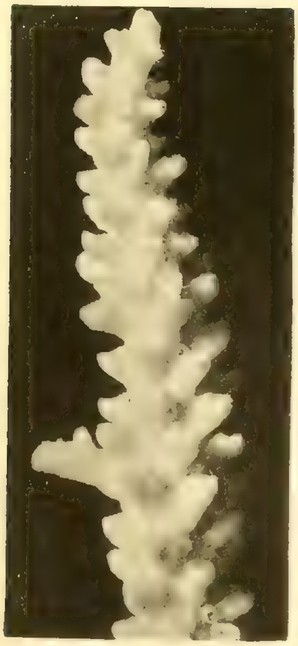
2

3 × ½

3a

3b ×3

FIGS. 1, 1*a*, 1*b*. *Acropora plicata* (Brook). FIG. 2. *Acropora variabilis* (Klz.). FIGS. 3, 3*a*, 3*b*. *Acropora variabilis* (Klz.) var.

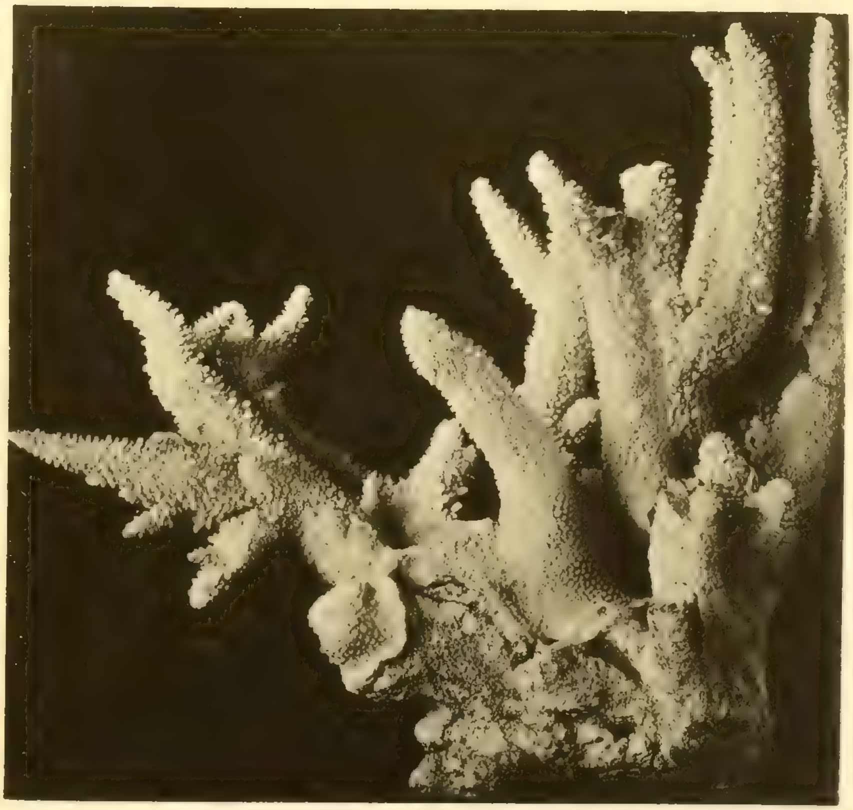


5 ×2

2 ×½

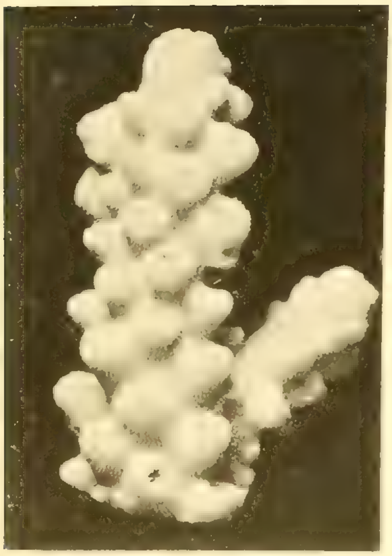
3 ×½

4 ×2



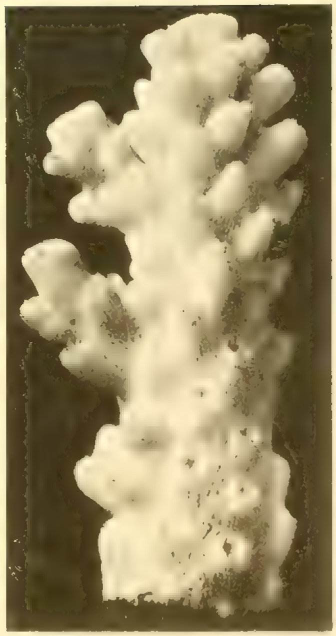
1 ×½

Acropora polymorpha (Brook).

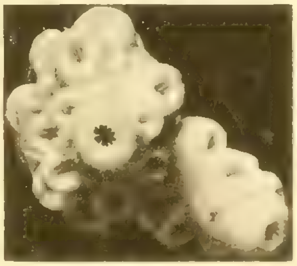


1a ×3

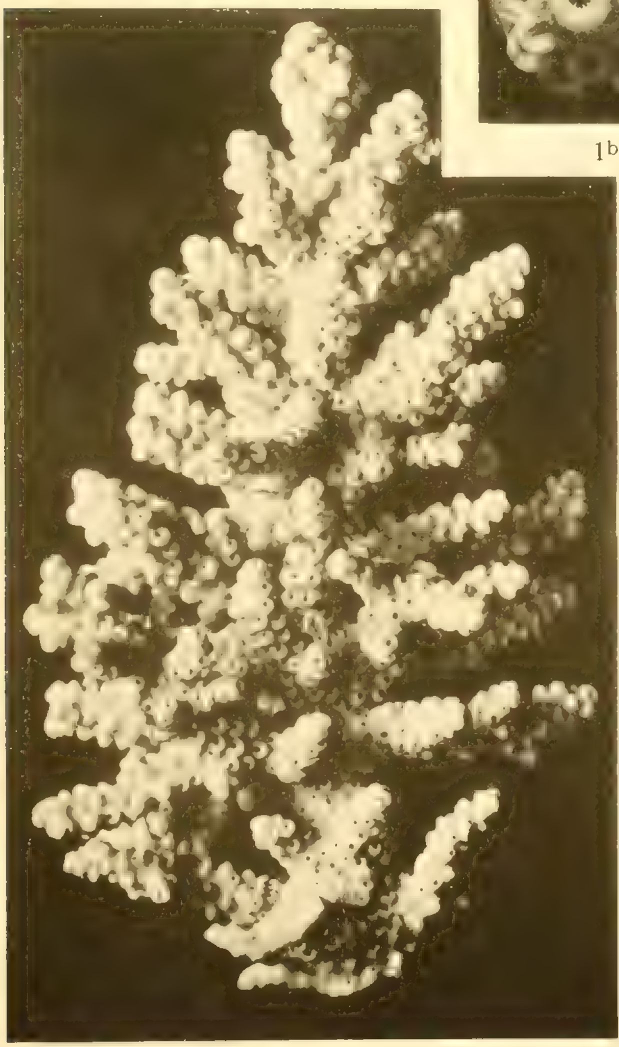
2b ×8



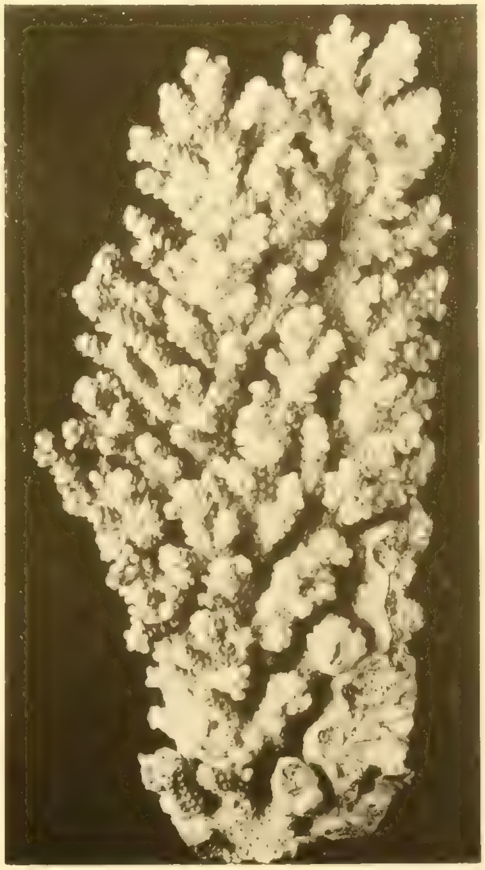
2a ×3



1b ×3

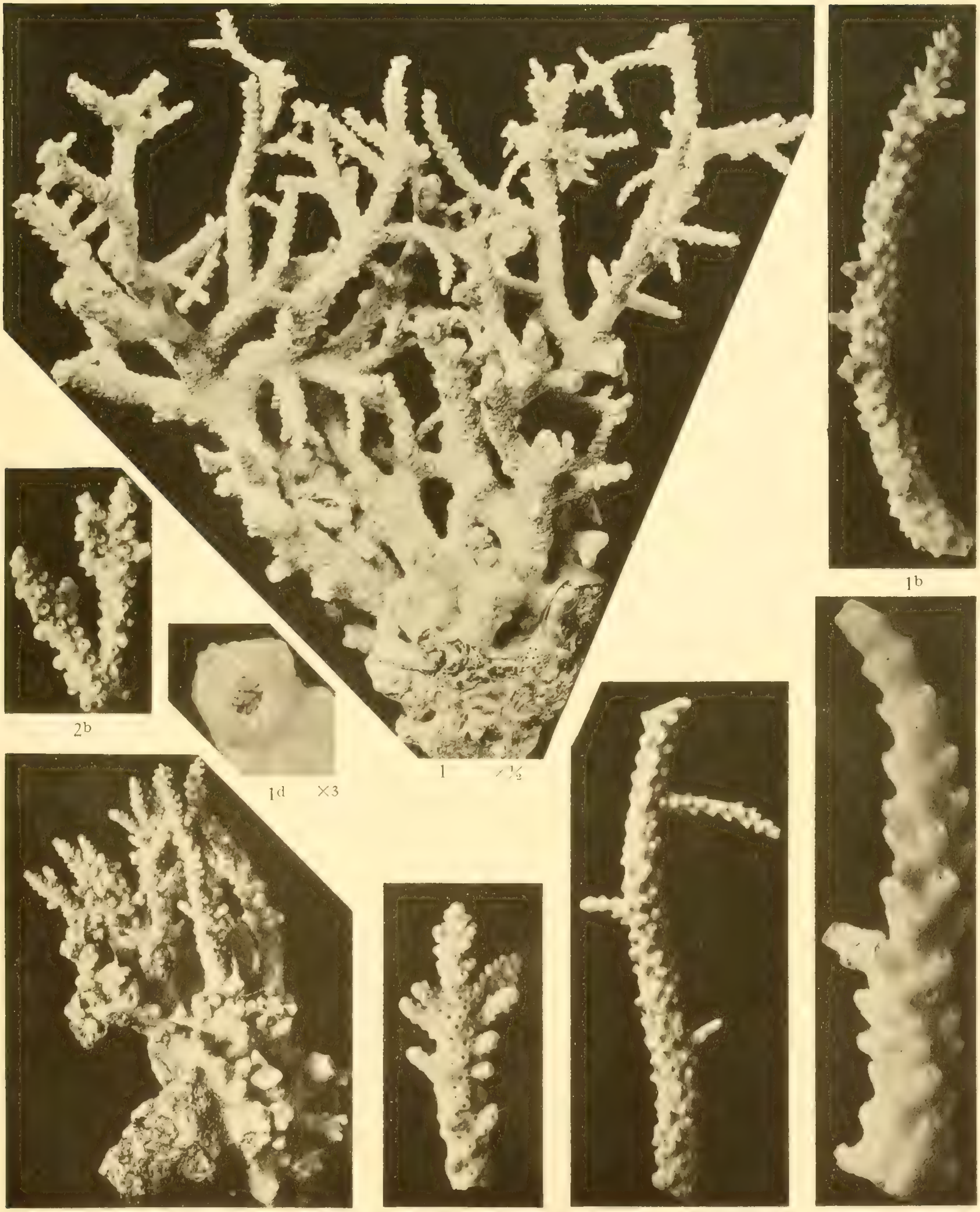


1



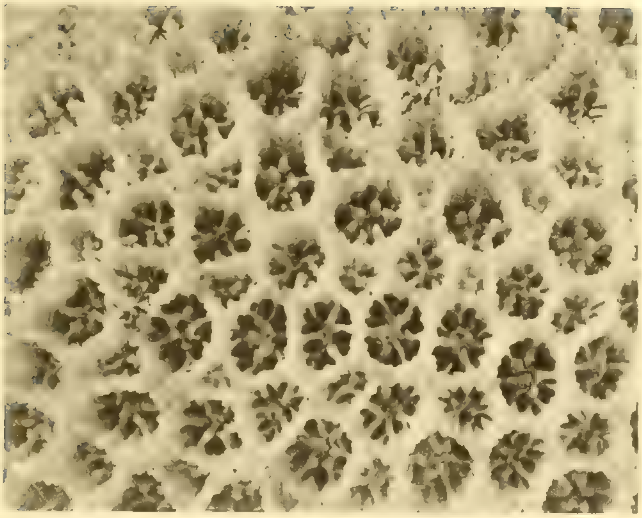
2 ×½

FIGS. 1, 1*a*, 1*b*. *Acropora murrayensis*, new species. FIGS. 2, 2*a*, 2*b*. *Acropora rosaria* (Dana).

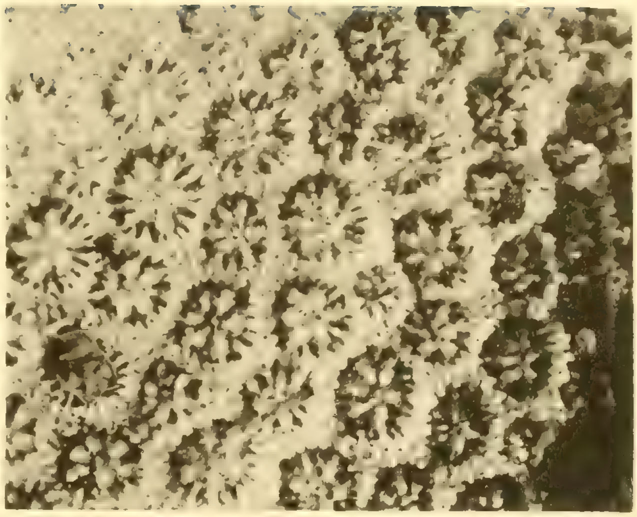


1 $\times \frac{1}{2}$ 1[b] 1[d] $\times 3$ 2[b] 2 $\times \frac{1}{2}$ 2[a] 1[a] 1[c] $\times 3$

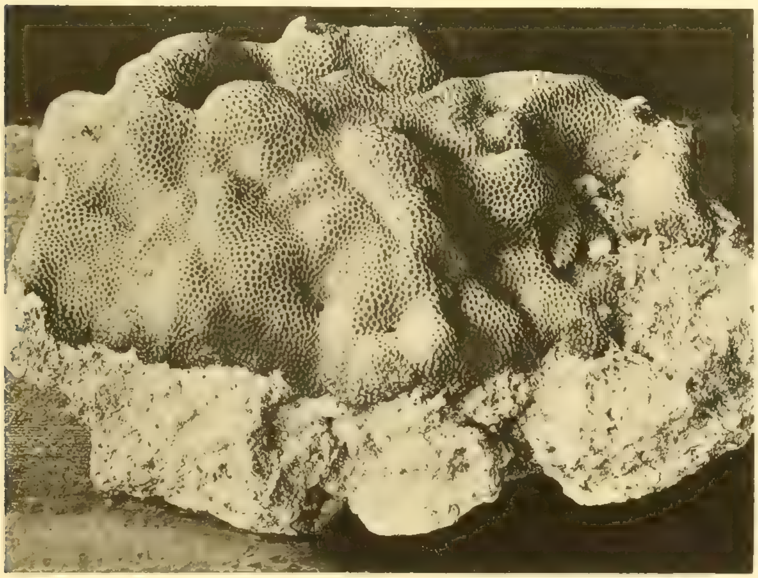
FIGS. 1, 1*a*-1*d*. *Acropora syringodes* (Brook). FIGS. 2, 2*a*, 2*b*. *Acropora squarrosa* (Ehr.).



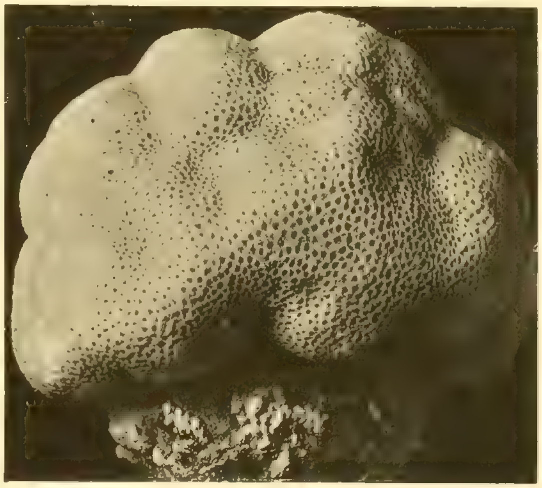
1 ×4



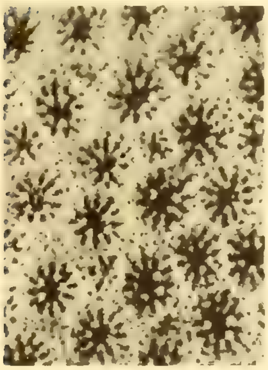
2 ×4



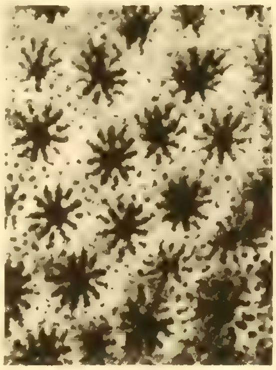
3



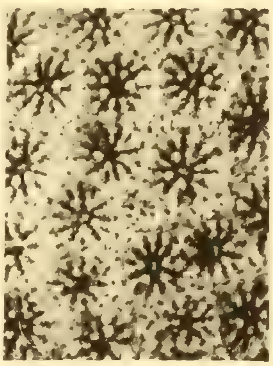
4



5 ×8



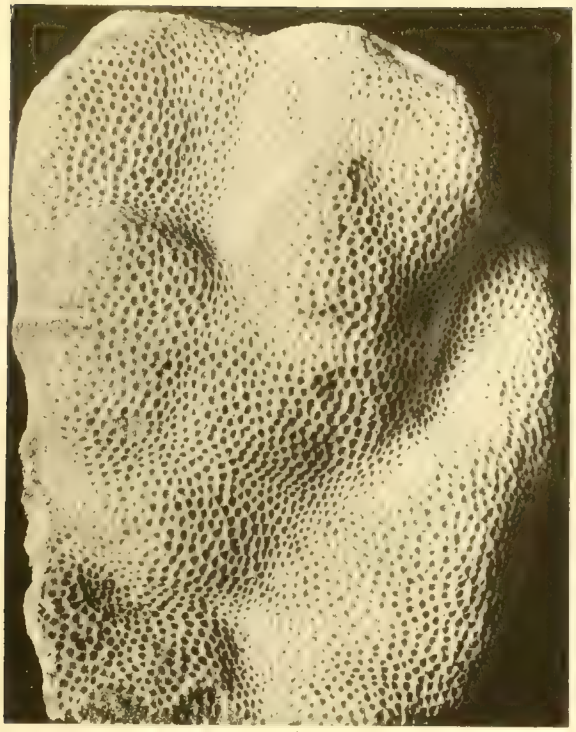
4a ×8



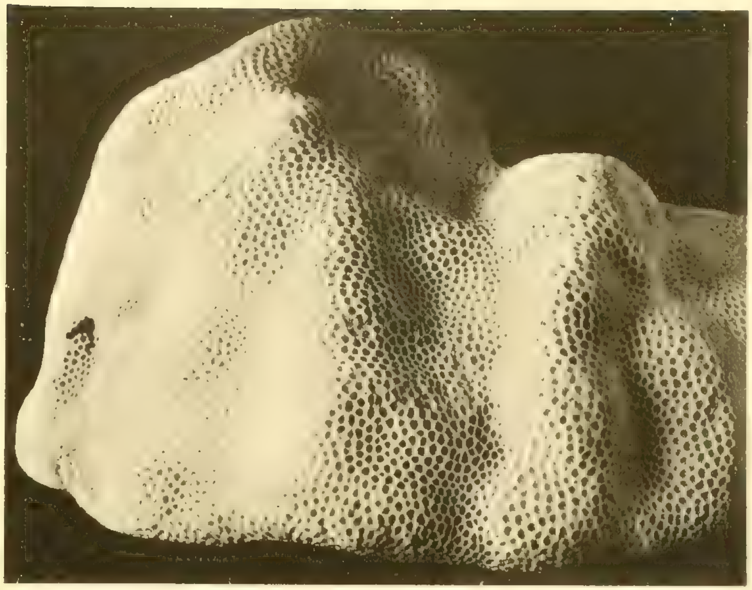
4b ×8

3a ×8

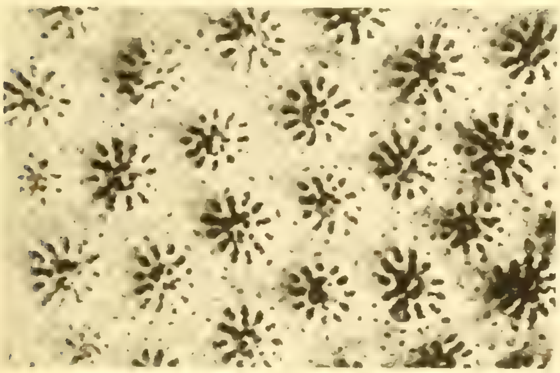
Figs. 1, 2. *Goniopora tenuidens* (Quelch). Figs. 3, 3a. *Porites solida* (Forsk.).
Figs. 4, 4a, 4b, 5. *Porites murrayensis*, new species.



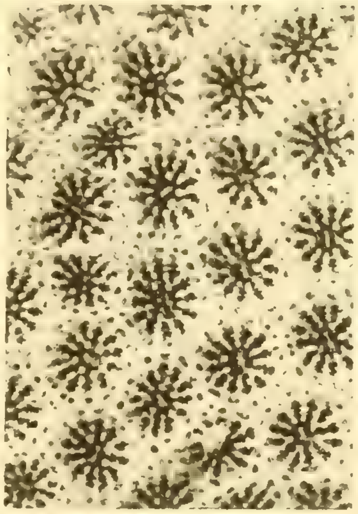
1



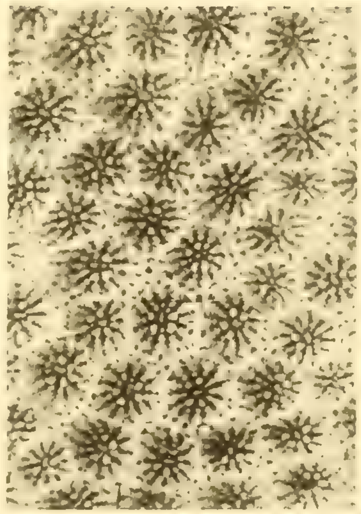
2



1a ×8

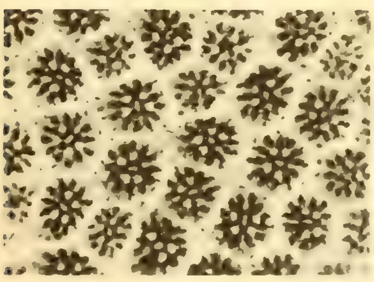


2a ×8

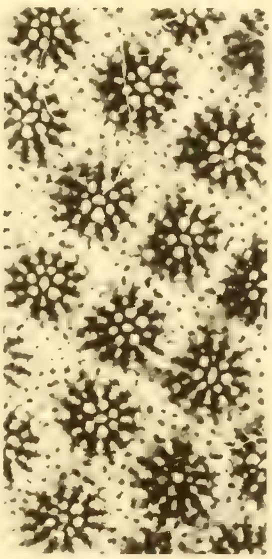


3 ×8

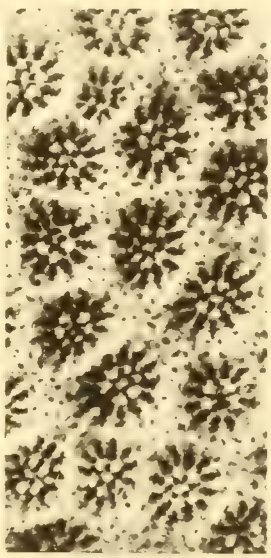
6



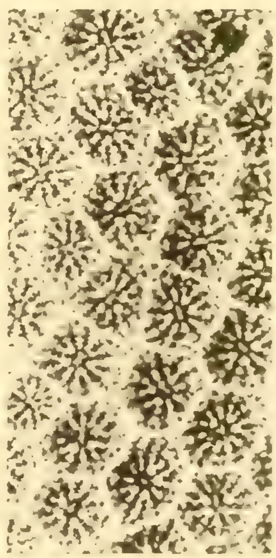
6a ×8



4 ×8

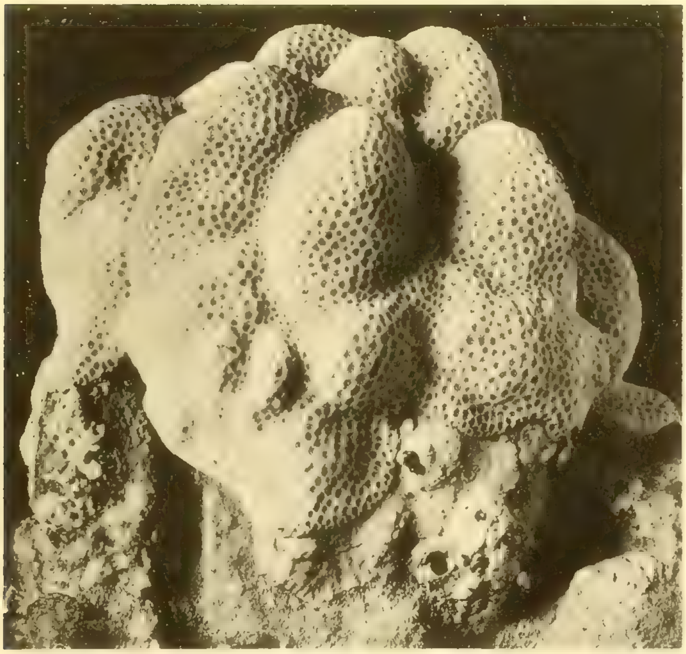


4a ×8

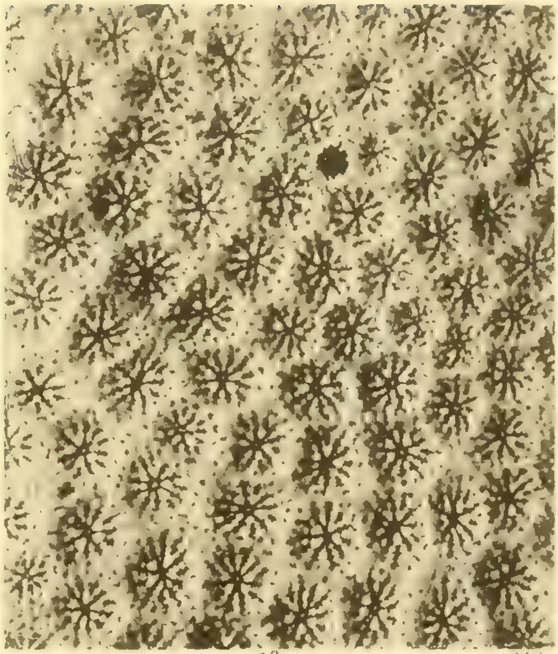


5 ×8

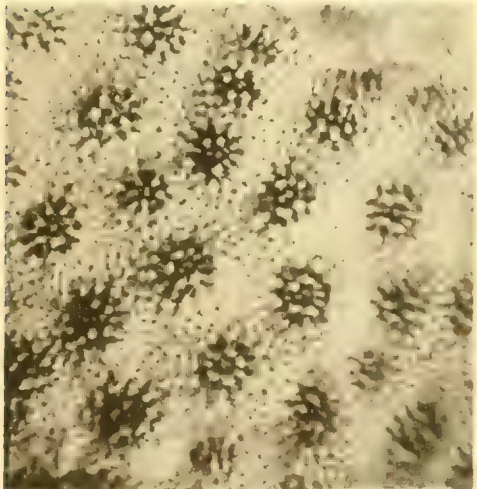
FIGS. 1, 1*a*, 2, 2*a*, 3. *Porites lobata* Dana. FIGS. 4, 4*a*, 5, 6, 6*a*. *Porites australiensis*, new species.



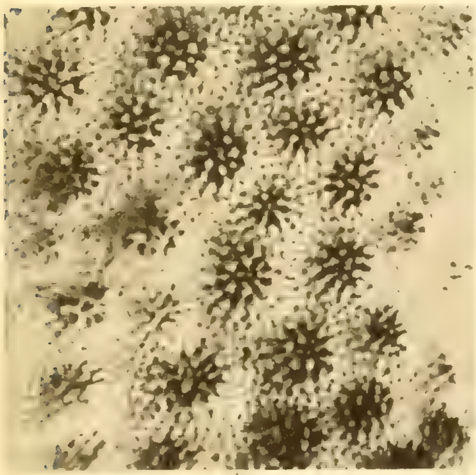
1



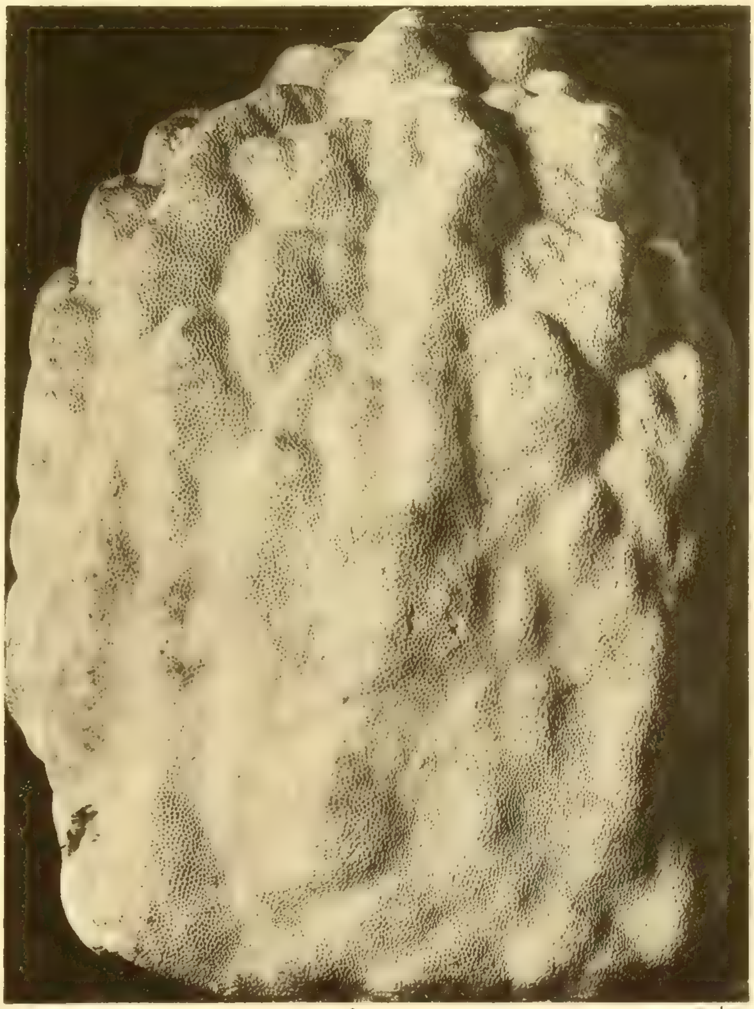
2a ×8



1a ×8

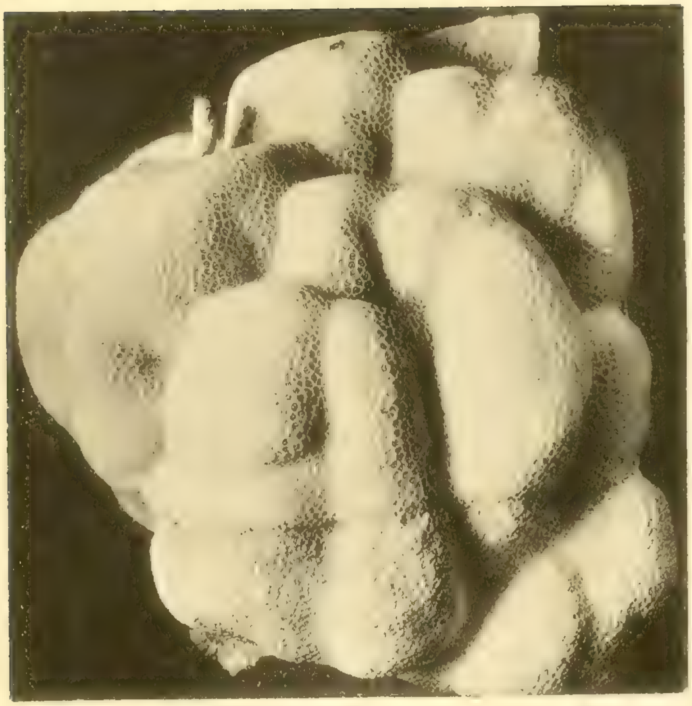


1b ×8

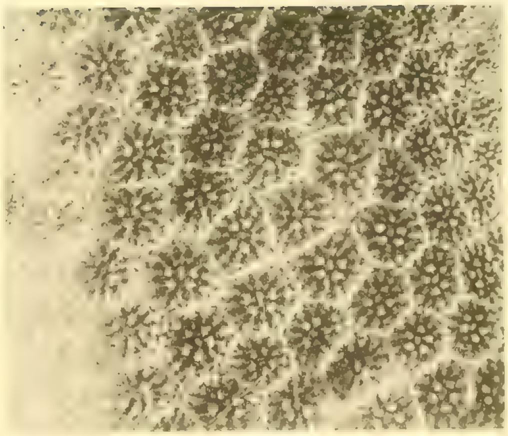


2 ×½

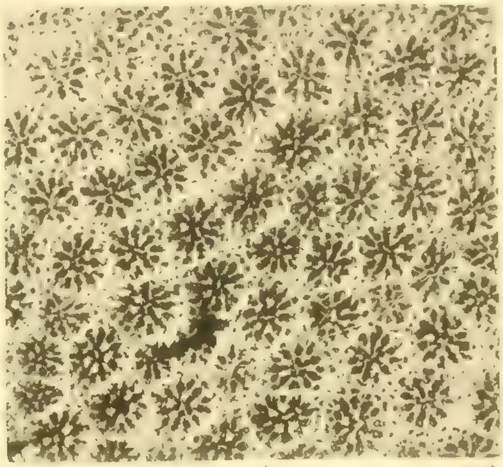
FIGS. 1, 1*a*, 1*b*. *Porites mayeri*, new species. FIGS. 2, 2*a*. *Porites fragosa* Dana.



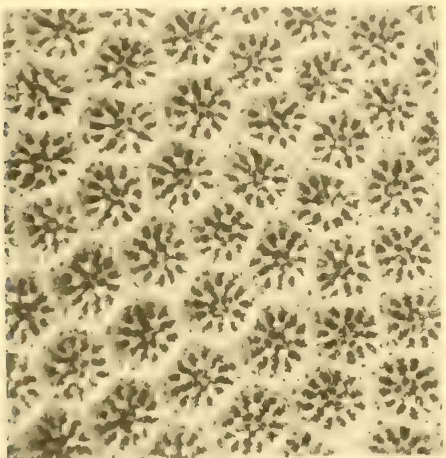
1



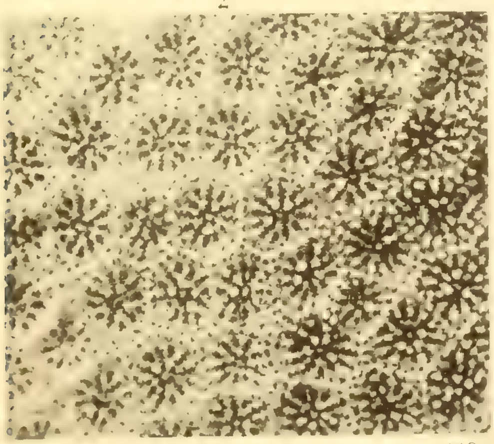
1^a $\times 8$



1^b $\times 8$



2^a $\times 8$

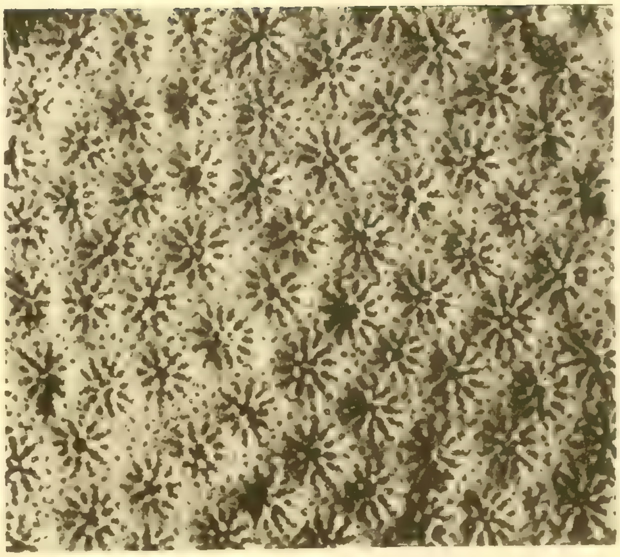


2^b $\times 8$

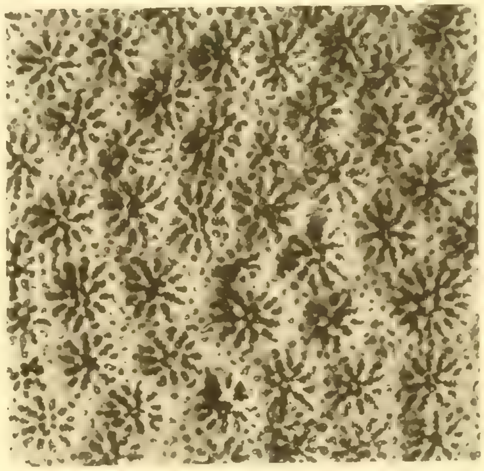
2 $\times \frac{3}{7}$

FIGS. 1, 1*a*, 1*b*. *Porites haddoni*, new species. FIGS. 2, 2*a*, 2*b*. *Porites somaliensis* Gravier.

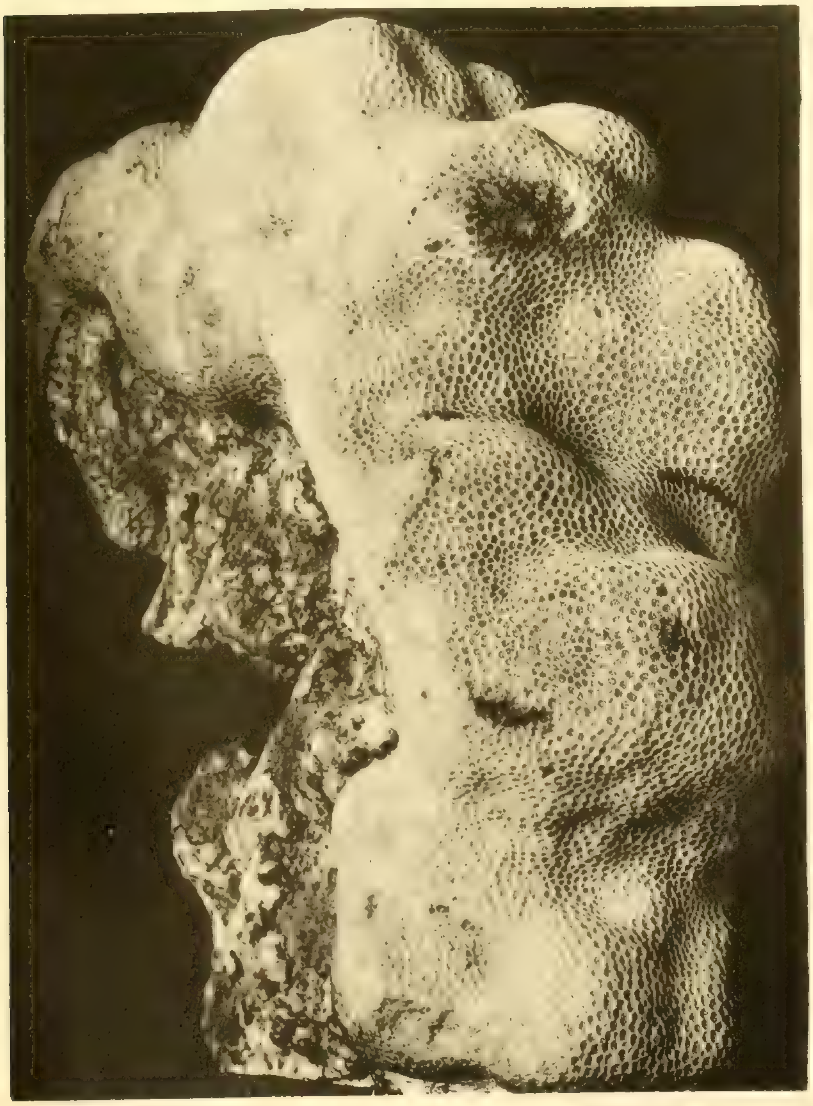
1



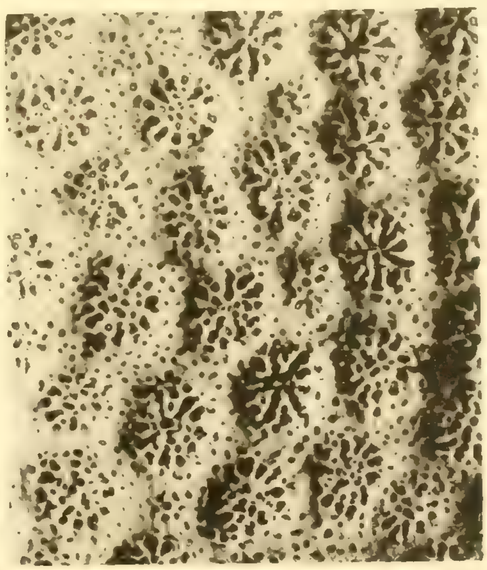
1^a × 8



1^b × 8



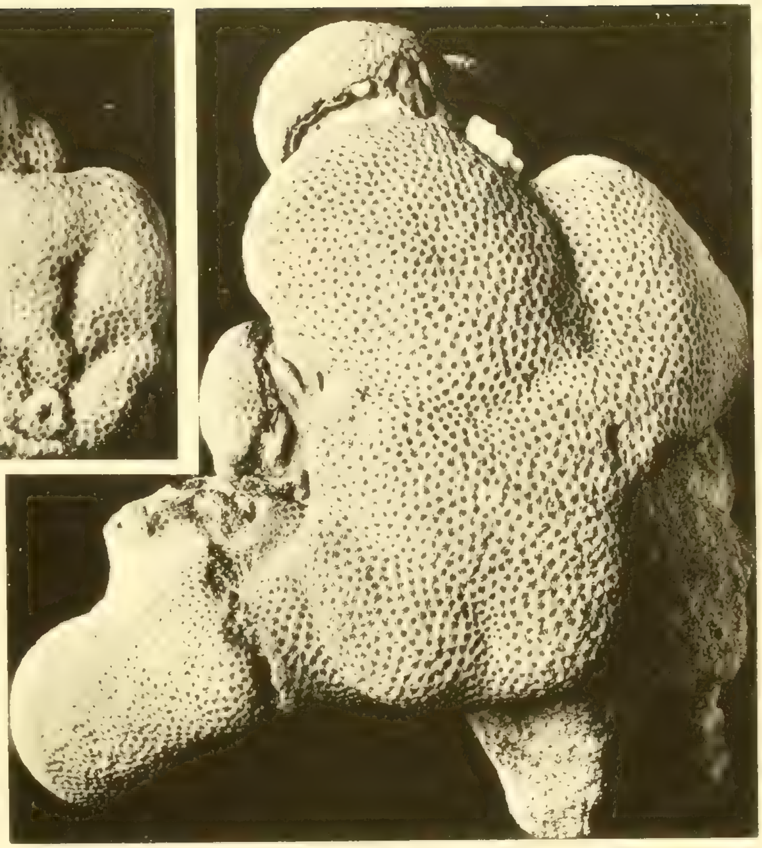
2



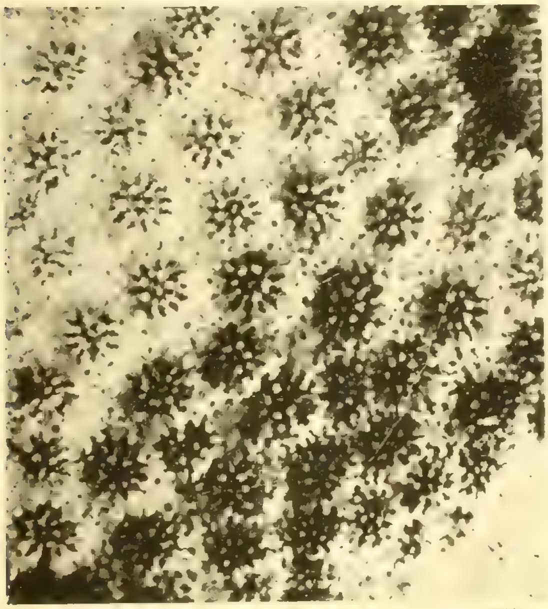
2^a × 8

FIGS. 1, 1*a*, 1*b*. *Porites lutea* M. Edw. FIGS. 2, 2*a*. *Porites limosa* Dana.

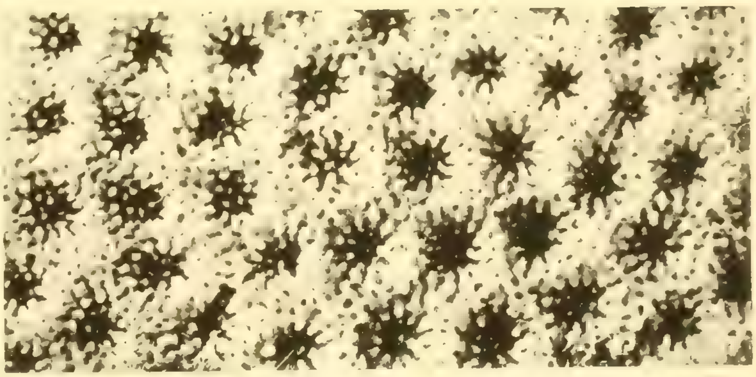
1



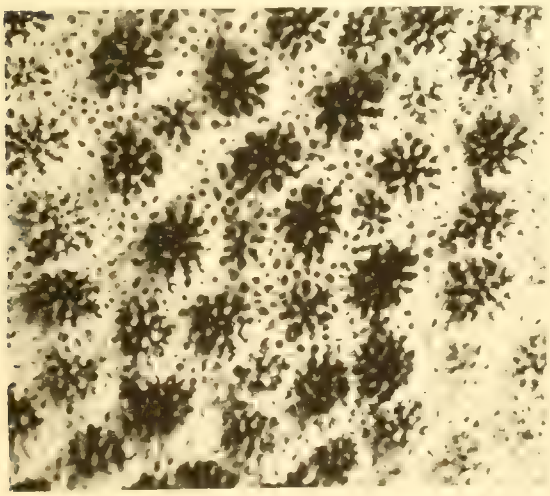
2



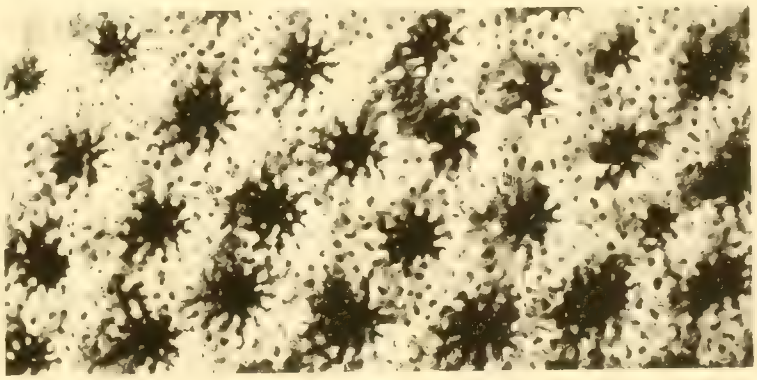
1a ×8



2a ×8

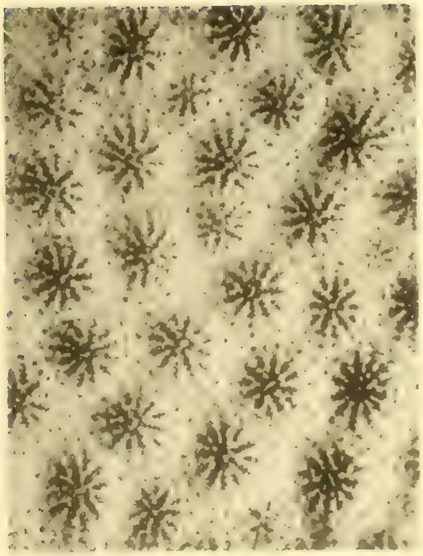


1b ×8

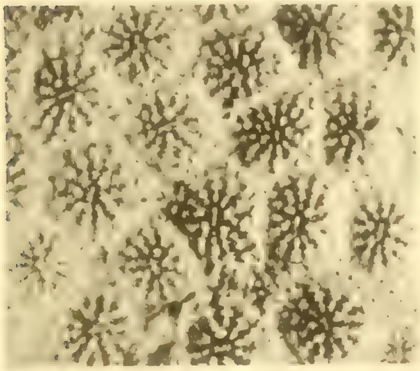


2b ×8

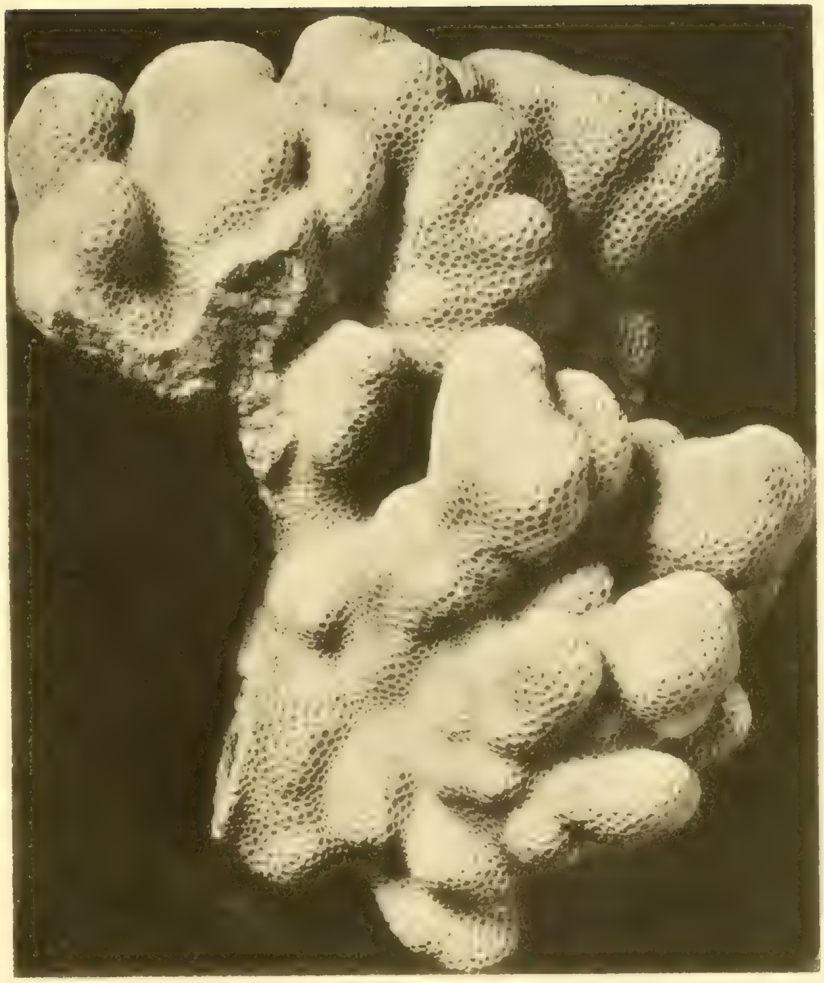
FIGS. 1, 1*a*, 1*b*. *Porites viridis* Gardiner. FIGS. 2, 2*a*, 2*b*. *Porites densa*, new species.



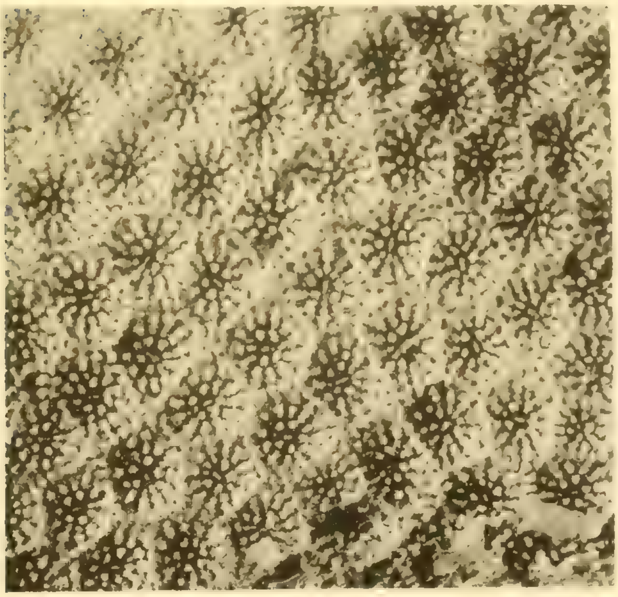
1a ×8



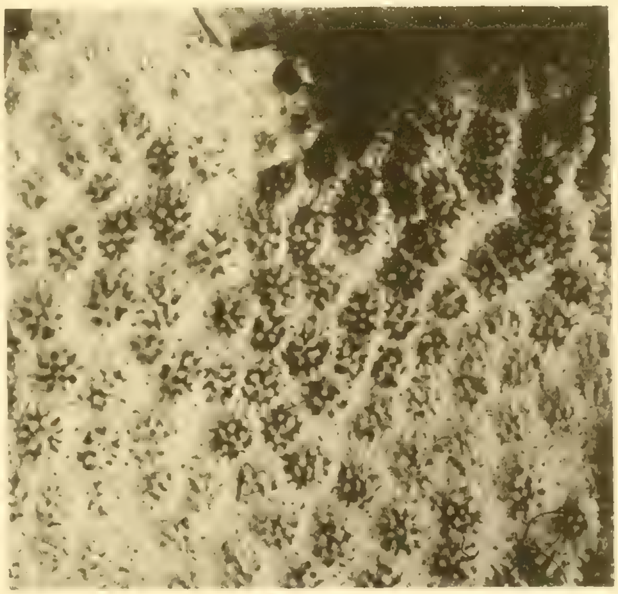
1b ×8



1

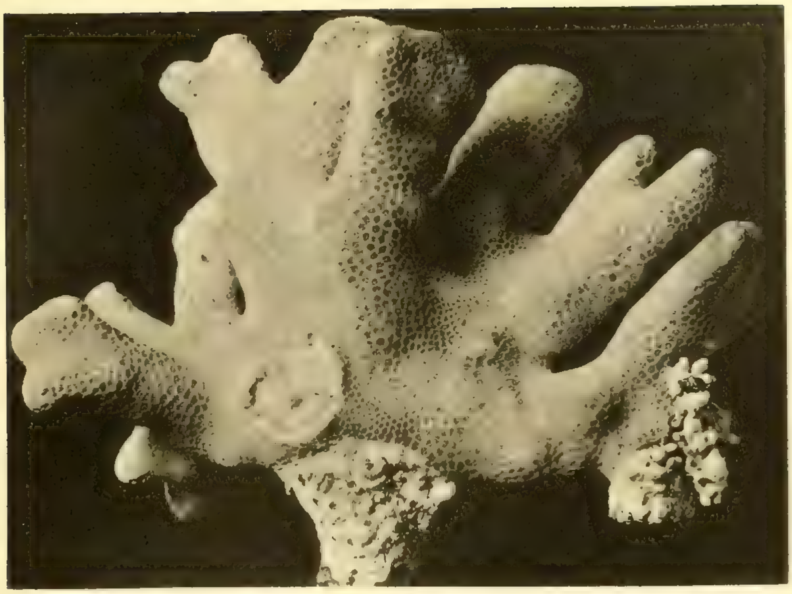


2 ×8

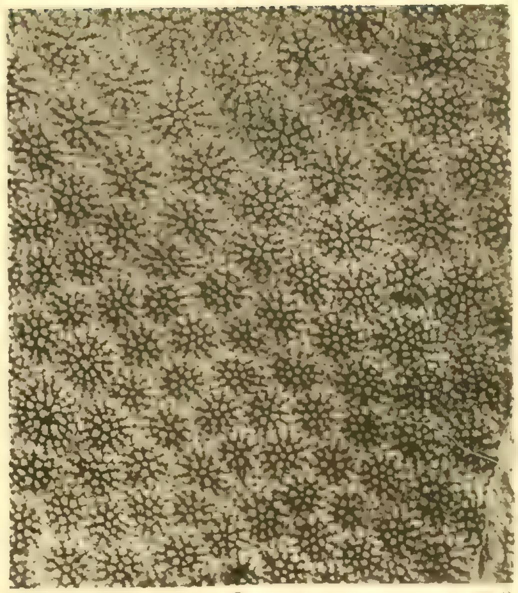


3 ×8

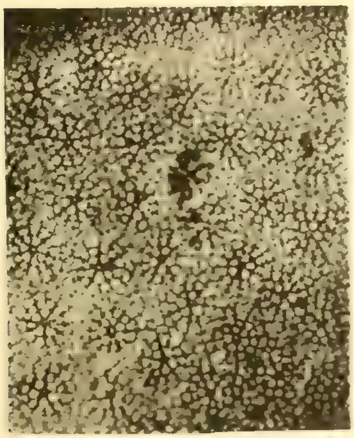
FIGS. 1, 1*a*, 1*b*, 2. *Porites pukoensis* Vaughan. FIG. 3. *Porites lichen* Dana.



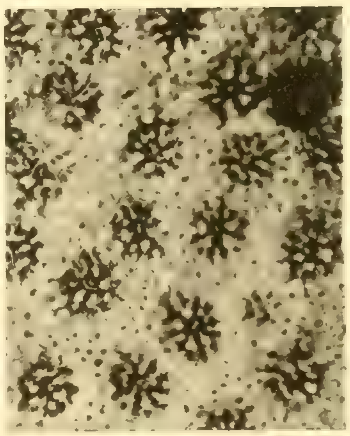
1



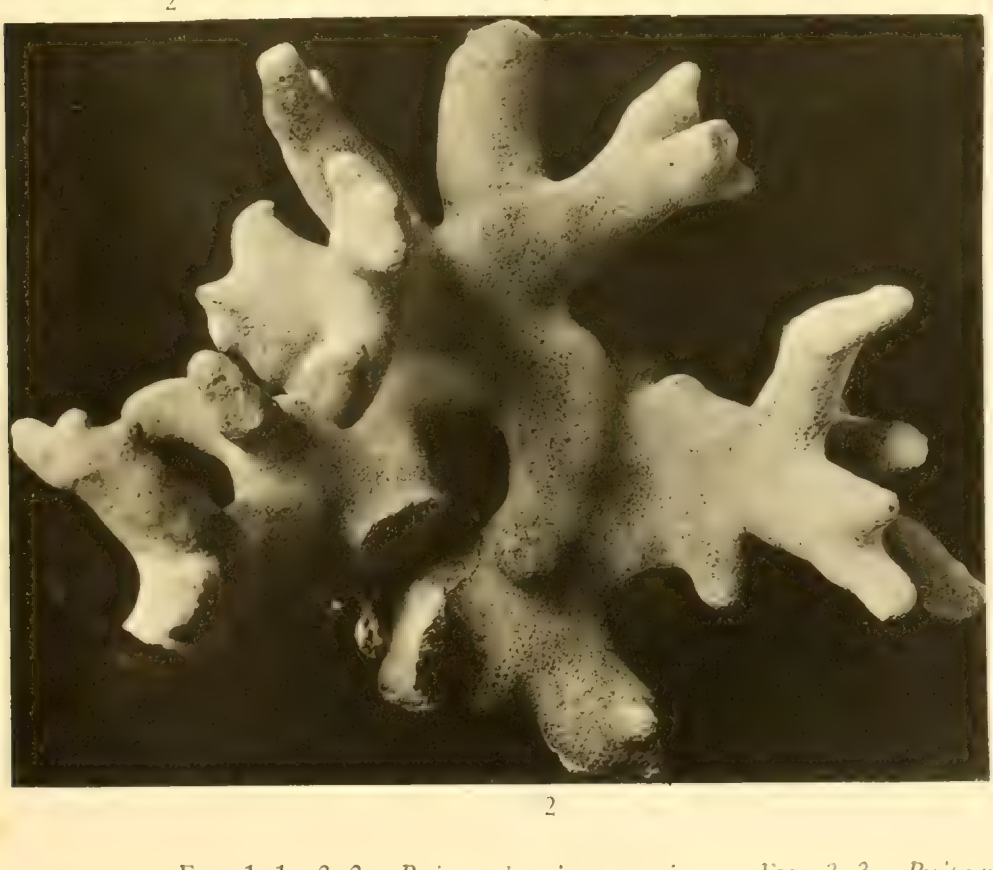
1[a] ×8



2[a] ×8



3[a] ×8



2

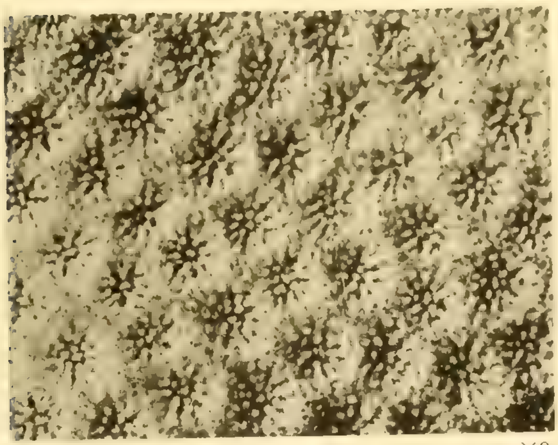
3

FIGS. 1, 1*a*, 2, 2*a*. *Porites andrewsi* new species. FIGS. 3, 3*a*. *Porites nigrescens* Dana.

2

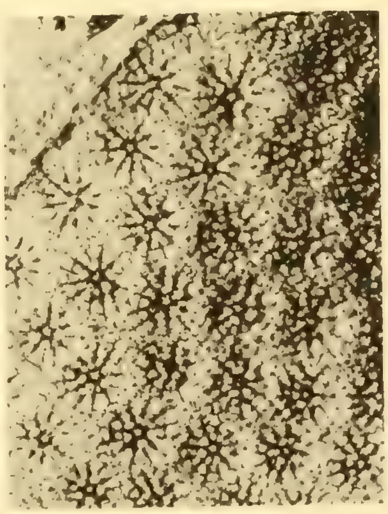
1

3

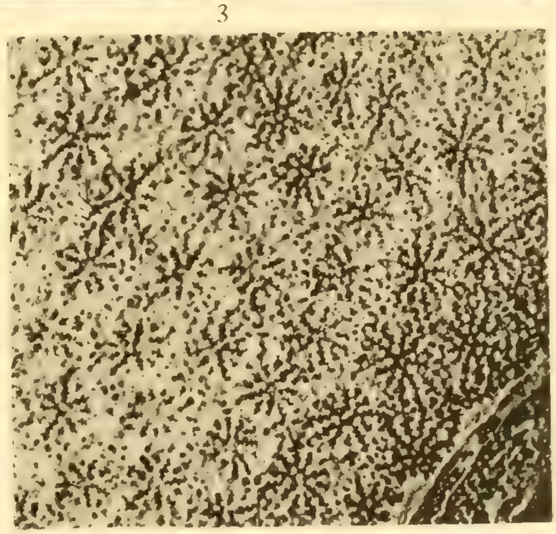


2a ×8

1a ×8

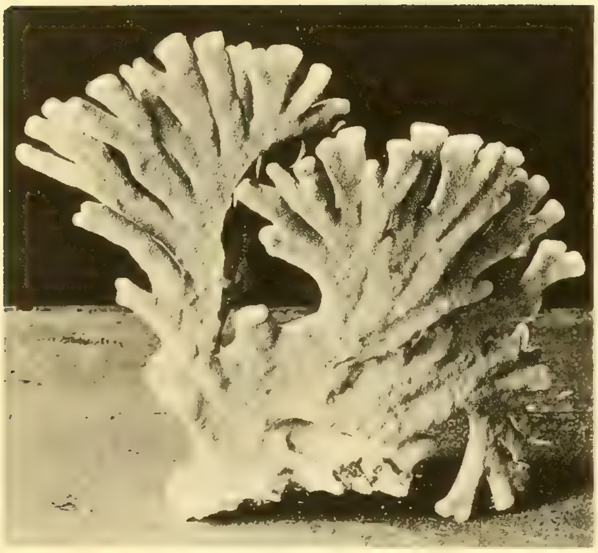


1b ×8



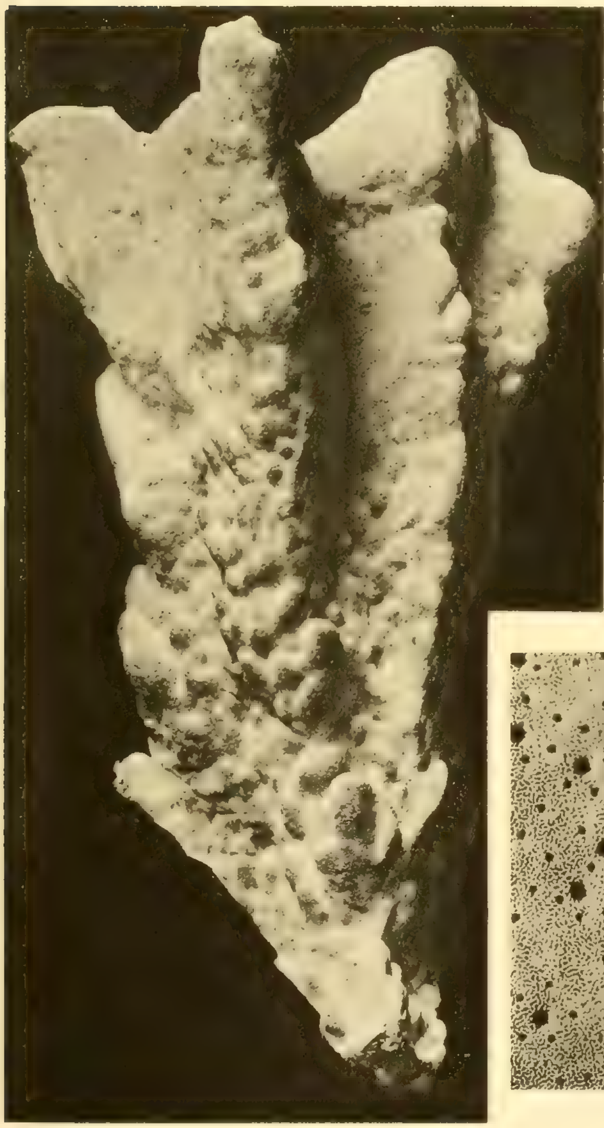
3a ×8

FIGS. 1, 1*a*, 1*b*. *Porites nigrescens* Dana. FIGS. 2, 2*a*. *Porites nigrescens* var. FIGS. 3, 3*a*. *Porites cylindrica* Dana.



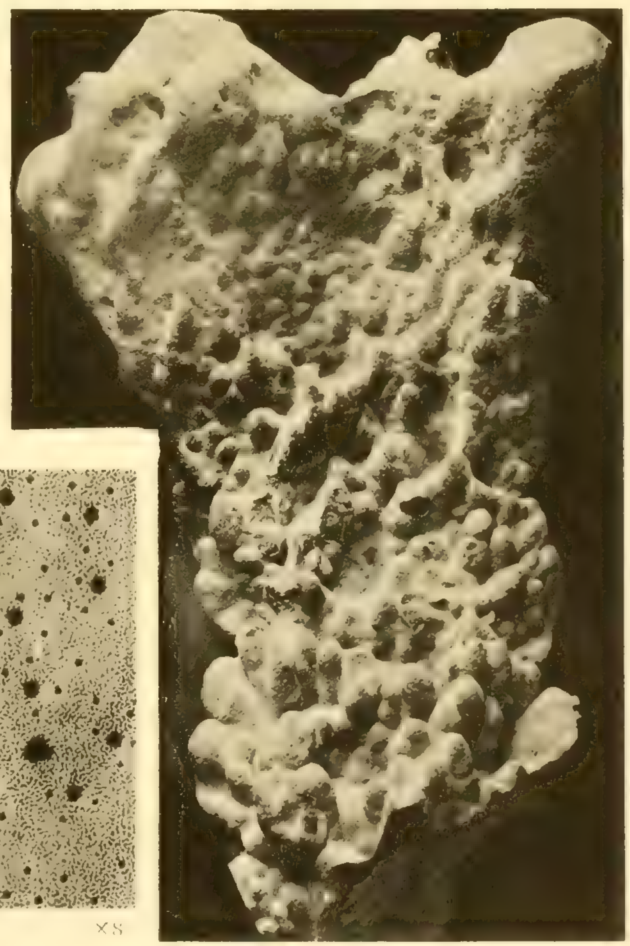
1 × 1/1

2 × 1/4



3 × 1/2

3b × 8



3a × 1/2

Fig. 1. *Millepora dichotoma* Fork. Fig. 2. *Millepora platyphylla* Ehr. Figs. 3, 3*a*, 3*b*. *Millepora truncata* Dana.

INDEX.

The following index contains the names of the higher groups and of the families, genera, species, varieties, and formæ of Madreporaria, which occur in this memoir. Two kinds of type are used for the names, roman and italic; the former indicates valid names, the latter synonyms. When a species name follows a genus name that is synonymous with another genus name, both the genus and species names of the combination are italicized, although the species name may be valid. Two kinds of type are used in the figures referring to the pages, the heavy-faced type indicates the pages on which descriptions may be found. The numbers from 211 to 219, inclusive, refer to the pages on which the explanations of the plates are given.

SOME SHOAL-WATER BOTTOM SAMPLES FROM MURRAY ISLAND, AUSTRALIA, AND COMPARISONS OF THEM WITH SAMPLES FROM FLORIDA AND THE BAHAMAS

By Thomas Wayland Vaughan

In collaboration with Joseph A. Cushman, Marcus Isaac Goldman, Marshall A. Howe, and others

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SALINITY OF OCEAN WATER AT FOWEY ROCKS, FLORIDA

By Richard B. Dole and Alfred A. Chambers

Chemists, U. S. Geological Survey

SOLUBILITY OF CALCITE IN SEA-WATER IN CONTACT WITH THE ATMOSPHERE, AND ITS VARIATION WITH TEMPERATURE

By Roger C. Wells

Physical Chemist, U. S. Geological Survey

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LIST OF PLATES.

TEXT FIGURES.

SOME SHOAL-WATER BOTTOM SAMPLES FROM MURRAY ISLAND, AUSTRALIA, AND COMPARISONS OF THEM WITH SAMPLES FROM FLORIDA AND THE BAHAMAS.

INTRODUCTION.

In order to have this investigation considered in its proper relations to coral reefs and their associated phenomena, I will refer to page 54 of my paper on the corals from Murray, Cocos-Keeling, and Fanning Islands, where it is said that "a complex of geologic processes operating in the area must be studied, analyzed, and evaluated. Among these are the agencies other than corals whereby calcium carbonate may be taken from the sea-water, the probability of the solvent action of sea-water on calcium carbonate," etc. In a previous publication[1] I made the statement:

"In order properly to evaluate corals as constructional agents, the subject needs to be studied from at least five different view points, viz: (1) In dealing with sediments uplifted above the sea, the quantity of material contributed by corals and that contributed by other agents must be estimated and the respective proportions determined; (2) in coral reef-areas, the proportion of the area covered by corals to that not covered by them should be estimated; (3) the relations of coral reefs to continuity and discontinuity of marginal submarine platforms must be ascertained; (4) marine bottom deposits must be analyzed according to the source of the material, and the percentage of the calcium carbonate contributed by the different agents estimated; (5) the rate of growth of corals needs to be known, especially for the light it may throw on the rate of reef formation."

In papers already published, I have devoted special attention to topics numbered 1, 2, 3, and 5, and have given some consideration to topic 4.[2]

The present paper is a preliminary contribution to the study of the marine bottom deposits in three coral-reef areas, viz: (1) Murray Island, Australia; (2) the Bahamas; (3) southern Florida. The Murray Island specimens were collected by Dr. A. G. Mayer. The samples from the Bahamas and Florida, here described, were collected mostly by me while working in association with Dr. Mayer, and have been selected, as representing certain important classes of deposits, from a lot of about 200 samples. I have previously discussed the calcium-carbonate sediments of these two areas in several of my papers on the geology of the areas (see bibliography on pp. 61, 62 in this volume, especially those treating of geology). Mechanical analyses have been made of all samples except those obtained in 1915, and the results of the chemical analyses of a selected set are here presented. The estimates of the percentage of the material contributed by different agencies is in progress and a report containing the results of all lines of investigation will be offered for publication.

[1] Carnegie Inst. Wash. Year Book No. 14, p. 222, 1916. [2] *Op. cit.*, pp. 222, 223.

The investigation of the source of the material, its mechanical state, and its chemical composition indicate certain classes of calcium carbonate deposits, some of them divisible into grades; and it is hoped that progress has been made toward outlining a method whereby an adequate classification of such sediments may ultimately be achieved. The deposits must not only be classified, but the areal extent of each must be determined, and, if possible, the volume of each should also be estimated.

PERCENTAGE OF INGREDIENTS ACCORDING TO SOURCE.

Calcium-carbonate deposits are derived initially from two sources: (1) through the activities of organisms which cause precipitation either inside or outside their tissues; (2) through chemical precipitation, either by inorganic agencies or by the activities of organisms which change the chemical composition of substances in solution in the water, producing supersaturation with reference to $CaCO_3$, or which by more purely physical processes may cause a state of supersaturation with reference to $CaCO_3$. In many marine sediments of to-day, in addition to that derived directly through the processes indicated, material is also derived from previously formed limestone which has been disintegrated and delivered to the sea.

In preparing for making percentage estimates of ingredients according to origin, a reliable reference collection had to be assembled. The preliminary working collection comprises oolitic limestones (thin sections and powders); calcium carbonate bacterially and inorganically precipitated in the laboratory; muds formed largely by bacterial action, although other agencies may have cooperated; coccolithophoridæ; thin sections and crushed fragments of calcareous algæ; a few radiolaria; over 100 named species and crushed fragments of common foraminifera; about 500 thin sections and crushed fragments of corals; mounted spicules of many species of alcyonaria; thin sections and crushed fragments of echinoids, bryozoa, mollusca, and crustacea. The collection is increased as the needs of the work require it.

Professor F. W. Clarke and Mr. W. C. Wheeler have rendered a valuable scientific service by chemically analyzing the skeletons of representatives of different groups of marine organisms. The completed results of the investigation have been brought together in a paper submitted for publication and entitled "The inorganic constituents of marine invertebrates and calcareous algæ," by F. W. Clarke and W. C. Wheeler.[1] Professor Clarke has kindly allowed the use of a copy of their manuscript while their paper is in press. The authors have shown that the chemical composition of the skeletons secreted by marine organisms varies from group to group, and that in certain groups, especially echinoids and alcyonaria, there is a definite relation between temperature and the ratio of $MgCO_3$ to $CaCO_3$, the magnesia being relatively higher in warm than in cold waters.

These investigations have rendered possible the correlation of the chemical composition of an entire sample with that of the various ingredients

[1]U. S. Geol. Surv. Prof. Pap. No. 102, pp. 56, 1917.

according to their source. Mollusks and stony corals, for instance, contain almost no $MgCO_3$, whereas certain foraminifera contain from 9 to 11 per cent, and coralline algæ sometimes contain as high as 20 per cent. Later in this paper the chemical composition of the deposits as ascertained by analysis will be compared with the chemical composition as deduced from the percentage of the respective organic ingredients forming them. This may be said here: if a sand in a coral-reef area contains 7.5 per cent of $MgCO_3$, probably not over 50 per cent of the deposit is of coral origin (see analyses of corallinaceous algæ on p. 248); and as mollusk shells and *Halimeda* contain almost no $MgCO_3$, and are generally present in coral areas, the probability is that less than 50 per cent of the deposit is coral.

SIZING OF SEDIMENTS.

The mechanical condition of a sediment is important in many particulars, for from it a number of deductions may be made. The particles in bottom samples usually fall into two categories: (1) those which preserve their original form, for example, the shells of many foraminifera, alcyonarian spicules, etc.; (2) particles which have a secondary form, resulting from (*a*) disintegration of the body of which it originally formed a part, (*b*) secondary aggregation of particles, as in oolite grains.

Agencies causing disintegration and reduction of size need brief consideration. These are of two classes: (1) inorganic; (2) organic. The inorganic agencies causing disintegration are waves and currents. Waves by their impact break structures or reduce the size by hurling fragments one against another. Both waves and currents reduce the size of particles by the attrition of one against another.

The numerous organic agencies which cause disintegration have been investigated by many students, among whom are Duerden, Stanley Gardiner, Wood Jones, and myself. Among the disintegrating agents are boring algæ, sponges, worms, mollusks, and echinoids. These all render calcareous structures less able to withstand the effects of waves and currents. Gardiner has properly emphasized the importance of sand-feeding organisms in the production of silt. I have made a number of similar observations on echinoids and holothurians in the Bahamas and in Florida. Some worms, and probably other organisms, also tend to reduce the size of particles. Unfortunately the amount of work accomplished by these agents has not been evaluated. It is a difficult task, and it will probably be some time before the order of magnitude may be ascertained. I have weighed the inorganic content of the guts of a number of holothurians and echinoids, and tried to ascertain the rate at which some passed sand, but the results seem unsatisfactory, as so many factors are unknown that no reliable estimate of effect is at present possible. The subject seems to me of sufficient importance to warrant special investigation. According to Darwin, H. O. Forbes, and Wood Jones, two species of *Scarus*, a genus of fishes, browse on living coral

and are thereby to be reckoned among the agents which break up calcium-carbonate structures.

Sizing is also of great importance, as it bears a most intimate relation to strength of waves and currents. Material of different sizes is not distributed in a haphazard way, but is collected according to definite physical laws in particular places. The relations of sediments to transporting agents and conditions of deposition have not yet been adequately studied; in fact, investigation of them is only now becoming definitely formulated; but enough is at present known to justify the statement in the preceding sentence.

The schedule of sizes here used is that of the Bureau of Soils, as Dr. Cameron, of that Bureau, was so kind as to have the mechanical analyses made there. This schedule meets the requirements of soil investigation, but geologic work needs something different. At present facilities for the special needs are not available, but it is the intention of the U. S. Geological Survey to install a laboratory equipped for this particular work as soon as practicable. The following statement gives the results of recent consideration of this problem by Messrs. M. I. Goldman, D. F. Hewett, G. S. Rogers, and E. W. Shaw:

"*Method of describing size of grains.*—It was apparent that in order to give readily a correct idea of the mechanical composition of sediments, and to be philosophic, the system of sizing should have regular intervals. The great majority of sedimentary rocks are composed of particles which have settled through some moving fluid, and since the proportion of grains of various sizes depends on the resultant sorting (the rate of fall of particles, other things being equal, varying with the square of their diameter), the ratio of sizes should be constant and should preferably be 4, 2, the square root of 2, or the fourth root of 2. Such a system of sizing, in contrast with the prevalent ones in which variable ratios are used, has the advantage that it does not give undue weight to a separate whose range in size is greater than others. If a variable ratio is used, the result does not give so good an idea of the composition of the sediment and is less significant as to its origin. If the analysis is made by counting and not by sieving, the constant ratio is more easily applied than a variable one, and the results of variable ratio analyses can be converted more readily and accurately to a fixed ratio system than they could to some other variable ratio system.

"In ordinary work it seems probable that the ratio 2 analysis will give sufficiently detailed information concerning the sediment. What will prove to be the most satisfactory starting-point is not yet evident, but presumably it will be either some point in the metric system, such as a centimeter, a millimeter, or a micron, or the figure adopted by the Bureau of Standards for a 200-mesh screen, viz, 0.074 mm."

It will be pointed out, in discussing the samples taken on the Murray Island reef flat and behind the reef off Cocoanut Point, Andros Island, Bahamas, that there is very little material of silt and clay size. The explanation of this condition demands consideration of the possibility of the removal of fine material (of the size of silt and clay) by means of solution by sea-water, a subject which will be discussed in its proper place (pages 265–268, and Dr. Wells's paper, pages 316–318).

BOTTOM DEPOSITS OF THE MURRAY ISLAND REEF.[1]

Dr. Mayer brought from Murray Island six bottom samples, five of which represent a section across the southeast reef along line I, and one is of a sand cast up on the reef 1,700 feet from shore, off the northwest end of the island. The five samples from line I are respectively from the following stations: above high tide, shore end; and 200, 600, 1,200, and 1,600 feet from shore. (See plate 2, of Dr. Mayer's article, for precise location.) He also brought specimens of the calcareous alga, *Goniolithon orthoblastum* (Heydrich) M. A. Howe, which is so important in the formation of the Lithothamnion ridge; of the limestone which is now elevated 500 to 700 feet above sea-level; and of the lava which, after being pushed upward through the limestone, was extruded over its surface. The lava has been examined by Professor Joseph P. Iddings, according to whom it is a basalt, rich in olivine. There is also some rotten volcanic tuff. The specimen of elevated limestone will be treated as if it were a bottom sample.

The following are Professor Iddings's notes on the basalt:

"Four specimens of basalt from Murray Island, Australia, are finely vesicular varieties, black, gray, and reddish brown in color. They are almost aphanitic, but carry minute phenocrysts of olivine less than 0.5 mm. in diameter in 3 specimens, and 1 mm. and less in the gray variety. They may be said to be minophyric and sempatic, there being about equal amounts of minute phenocrysts and groundmass in each variety, and as there is a gradation in the sizes of the phenocrysts from the largest to those that are indistinguishable from the microscopic crystals in the groundmass, their fabric is seriate porphyritic.

"The mineral composition of the four specimens is quite uniform, and consists of olivine, which forms the most noticeable phenocrysts, less augite, and about the same amount of strongly calcic plagioclase feldspar in microscopic prismoids.

"The two black varieties have a brown-glass base, with abundant microlites of the minerals just named, besides much magnetite or titaniferous iron oxide in delicately dendritic clusters.

"In the reddish-brown variety the iron oxide and outer portions of the mafic or ferromagnesian minerals are reddened. The gray basalt is apparently holocrystalline; is rich in olivine and violet-tinted augite, with dendritic magnetite and prismoids of plagioclase.

"From the mineral composition it is to be inferred that this basalt is low in silica and the alkalies, and is rich in iron oxide, magnesia, and lime, with normal alumina, and considerable titanium oxide."[2]

The bottom specimens were collected by immersing a bottle and scooping up the material. It is believed that they are fairly representative, for they were taken where about an average amount of coarse material was present and probably very little fine material was washed out as the

[1]For a preliminary note, see Carnegie Inst. Wash. Year Book No. 14, p. 220.

[2]Descriptions of the volcanic rocks of Maër Island are given by Haddon, Sollas, and Cole in Trans. Roy. Irish Acad., vol. 30, pp. 432-437, 1894.

sample was taken. The following work has been done on them: (1) mechanical analyses were made at the U. S. Bureau of Soils, under the direction of Dr. F. K. Cameron, formerly chemist of that Bureau; (2) chemical analyses were made of the samples and of certain important foraminifera by W. C. Wheeler and Alfred A. Chambers in the U. S. Geological Survey Chemical Laboratory; (3) Dr. Albert Mann, of the U. S. Bureau of Plant Industry, has furnished a list of the diatoms; (4) Dr. Marshall A. Howe, of the New York Botanical Garden, has prepared a report on the calcareous algæ; (5) Dr. J. A. Cushman, of the U. S. Geological Survey, has written a report on the foraminifera; (6) Dr. Marcus I. Goldman, of the U. S. Geological Survey, undertook to determine for two specimens the percentage of ingredients according to origin.

SOURCES OF THE MATERIAL.

Chemically precipitated material.—Inspection of the mechanical analyses on page 246 shows that on line I the maximum content of silt and clay is 600 feet from shore, where it is 2.8 per cent; while the minimum is at 1,200 feet from shore, where it is only 0.9 per cent. The analyses indicate the presence of very little bacterially or inorganically precipitated calcium carbonate, as such material originally, at least, is very finely divided. Should such precipitation have taken place, nearly all the material has been removed.

Coccolithophoridæ.—Some of these organisms are found in the sediments of silt size, and coccoliths occur in that of clay size, but in these samples they are of decidedly subordinate importance as contributors of material.

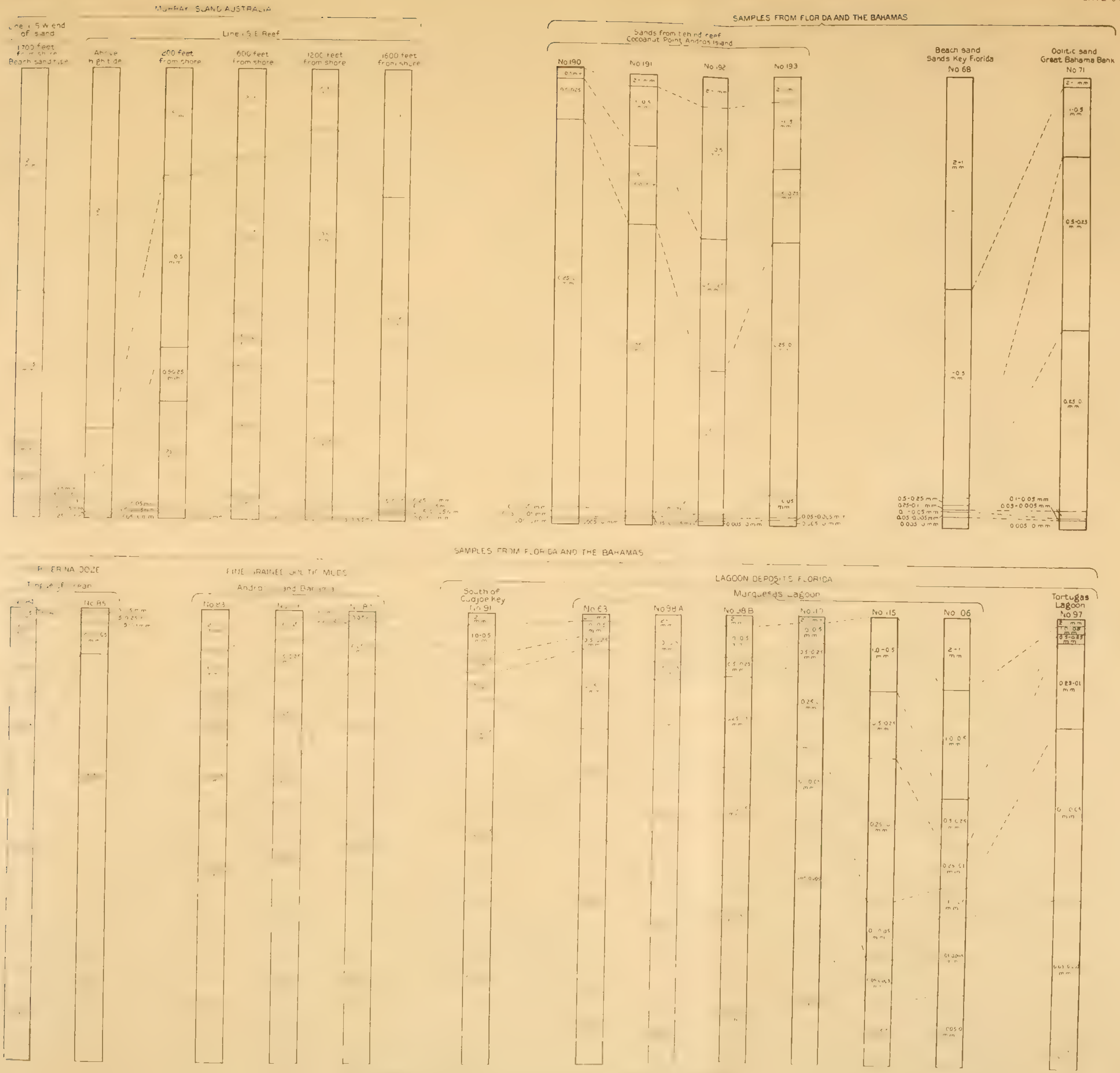
Diatoms.—These are present, but in an unimportant amount. An account of them by Dr. Mann may be found on page 297 of this volume.

Coralline algæ.—These organisms are of great importance and are specially described by Dr. Howe. (See pages 291–296 of this volume.) Besides forming what Dr. Mayer designates the "Lithothamnion ridge," they incrust nearly all the dead coral and are important contributors of $MgCO_3$.

Foraminifera.—This, another highly important group, is reported on in detail by Dr. Cushman, pages 289–290 of this volume. *Polytrema mineaceum* (plate 97, figures 1, 1*a*) incrusts much of the dead coral, as it does in nearly every place where reef-corals are found.

Madreporaria.—Dr. Mayer has discussed the abundance of this group, and I have described the fauna in the paper which precedes this one.

Alcyonaria.—This group is given a caption, as it is important in the Bahamas and Florida. Spicules occur in nearly every, if not every, shoal-water sample which I have examined from those areas, but there are few or none in the Murray Island specimens. The abundance of such spicules in samples from the former area, and their scarcity or absence in samples from the latter, constitute the most striking difference between reef samples from the two areas. However, in other Australian reef areas they are probably important, as Alcyonaria are abundant in many places, and especially in



Graphic illustration of mechanical analyses of bottom samples.

areas where silt is being deposited, for there *Sarcophyton* and *Xenia* grow plentifully.

Echinoids.—Very few echinoid fragments were observed.

Mollusca.—This is another important group, as it contributes a large proportion of the bottom material.

Bryozoa and Crustacea.—Some fragments of barnacle plates, ostracods, and other crustacea were found, but no bryozoa were recognized.

The four groups of organisms which are most important are, named in systematic order: (1) coralline algæ; (2) foraminifera; (3) madreporarian corals; (4) mollusca.

DISTRIBUTING AND SORTING AGENTS.

The following statement is quoted from Dr. Mayer's article (page 8 of this volume):

"The strong southeast trade-wind, which prevails for about eight months of the year, causes the ocean water on the incoming tide to sheer near the middle of the southeast side of Maër Island, the currents parting, the stronger going around the southwestern and the weaker around the northern end of the island. The current around the southwestern side is reinforced by that around Dowar Island and is thus stronger than that around the northeastern end. The silt from Haddon and Hedley brooks is thus carried around the southwestern end of the island and contributes to form the sand dunes, which are about 20 feet high, and to cover partially and smother the reef-flats at the western corner of Maër Island. (See map, plate 2, and fig. 10.) Several smaller sand dunes on the northern corner of the island are also formed by the weaker northeasterly currents, and thus the northwest side of the island is concave and lined throughout by a sand beach formed of volcanic and calcareous fragments. It is interesting to observe that the sand derived from these currents is tending to change the original oval shape of the island into a crescent, reminding one of the manner in which an atoll islet acquires its typical crescentic shape, as shown by Guppy, Hedley and Taylor, Wood Jones, and Vaughan. The outflowing currents due to the falling tide are not competent to offset this effect, for they must make their way against the prevailing southeast wind. At the Murray Islands the tide rises between 7 and 8 feet, thus producing spring tide currents of nearly 4 knots an hour around the southern end and a flow of about half that rate around the northern end of the island."

As will later be shown, there is very little fine material in the samples from the southeast reef of Murray Islands and the proportion there is essentially the same as in the samples taken from behind the reef off Cocoanut Point, Andros Island, Bahamas. In both instances, in my opinion, the explanation of the small percentage of particles of silt and clay size is attributable to outwash by currents and not to submarine solution.

MECHANICAL AND CHEMICAL ANALYSES.

The following tables show the results of mechanical analyses of the Murray Island bottom samples and chemical analyses of the bottom samples, of certain foraminifera important as contributors to deposits in coral-reef areas, and of calcareous algæ from Murray Island and Cocos-Keeling Islands.

Mechanical analyses of samples from Murray Island.

(By U. S. Bureau of Soils.)

[The results of these analyses are graphically shown on plate 94.]

No., U. S. Bureau of Soils.	Description.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
		p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
27336	Line I, above high tide, shore end	80.1	18.5	0.6	0.2	0.1	0.1	0.2
27337	Line I, 200 feet from shore	23.6	37.9	12.2	23.2	.7	.7	1.2
27338	Line I, 600 feet from shore	19.0	34.9	11.5	28.5	2.5	1.6	1.2
27339	Line I, 1,200 feet from shore	3.0	66.1	26.3	3.2	...	.2	.7
27353*a*	Line I, 1,600 feet from shore	27.1	66.2	4.0	.5	.1	.3	1.4
27340	Line III, north end, 1,700 feet from shore.	49.4	33.1	3.0	9.6	1.0	1.7	1.5

Chemical analyses of Murray Island bottom samples.

(By Alfred A. Chambers.)

Chemical analyses of bottom samples.						
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Loss on ignition	44.89	44.51	44.87	44.96	45.24	43.86
SiO_2	.23	.31	.09	.07	.22	.16
$Fe_2O_3+Al_2O_3$	.35	.30	.21	.10	.26	.27
CaO	50.80	51.54	50.86	51.41	49.80	55.35
MgO	2.69	2.58	2.75	2.68	3.49	.28
P_2O_5	.00	.00	.00	.00	.00	.00
SO_3	Trace.	Trace.	Trace.	Trace.	Trace.	.00
Na+K	Trace.	Trace.	Trace.	Trace.	Trace.	(?)
Total	98.96	99.24	98.78	99.22	99.01	99.92
CO_2 needed	42.87	44.34	42.98	43.33	42.87	43.72
Reduced analyses (hypothetical combinations).						
SiO_2	0.24	0.32	0.09	0.07	0.23	0.16
$(Al, Fe)_2O_3$	.36	.31	.22	.10	.27	.27
$MgCO_3$	5.83	5.52	5.95	5.76	7.57	.60
$CaCO_3$	93.57	93.85	93.74	94.07	91.93	98.97
$Ca_3P_2O_8$	.00	.00	.00	.00	.00	.00
$CaSO_4$	Trace.	Trace.	Trace.	Trace.	Trace.	.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

No. 1, Murray Island, line I, southeast reef, 1,600 feet from shore. Water, 10 inches deep; low tide, October 2, 1913.
No. 2, Murray Island, line I, southeast reef, 200 feet from shore. Water, 4 inches deep.
No. 3, Murray Island, line I, southeast reef, 600 feet from shore. Water, 7 inches deep at low tide.
No. 4, Murray Island, line I, southeast reef, 1,200 feet from shore. Water, 12 to 16 inches deep at low tide.
No. 5, Murray Island, line III, north end, 1,700 feet from shore, washed up on reef above low-tide level.
No. 6, Murray Island, limestone from 500 to 700 feet above sea-level.

Chemical analyses of foraminifera important as contributors to deposits in coral-reef areas.

(1) *Tinoporus baculatus* (Montfort) Carpenter, from Murray Island.
(2) *Polytrema mineaceum* (Linn.), from Cocoanut Point, Andros Island, Bahamas.
(3) *Orbiculina adunca* (Fichtel and Moll), from Key West, Florida.
(4) *Orbitolites marginalis* (Lam.), from south of Tortugas, depth 17 fathoms.
(5) *Quinqueloculina auberiana* d'Orbigny, from south of Tortugas, depth 17 fathoms.

Analyses of 1, 2, 3, 4, by W. C. Wheeler; of 5 by Alfred A. Chambers.

	Chemical analyses of foraminifera.				
	(1) Tinoporus.	(2) Polytrema.	(3) Orbiculina.	(4) Orbitolites.	(5) Quinque-loculina.
SiO_2	0.03	0.02	0.11	0.30	0.54
$(Al, Fe)_2O_3$	.18		.09	.13	
MgO	5.03	5.09	4.64	4.93	4.32
CaO	27.35	47.35	48.79	48.92	49.02
P_2O_5	.00	(?)	Trace.	Trace.	(?)
Ignition[1]	46.57	46.24	45.56	45.20	45.54
Total	99.16	98.70	99.09	99.48	98.42

	Reduced analyses (hypothetical combinations).				
	(1) Tinoporus.	(2) Polytrema.	(3) Orbiculina.	(4) Orbitolites.	(5) Quinque-loculina.
SiO_2	0.03	0.02	0.11	0.31	0.56
$(Al, Fe)_2O_3$	.19		.09	.13	
$MgCO_3$	11.08	11.22	10.04	10.55	9.33
$CaCO_3$	88.70	88.76	89.76	89.01	90.11
$Ca_3P_2O_8$	.00	(?)	Trace.	Trace.	(?)
Total	100.00	100.00	100.00	100.00	100.00
	Murray Id.	Bahamas.	Key West.	Tortugas.	Tortugas.

[1] Organic matter + CO_2 + H_2O.

Analyses of Corallinaceous algæ (made by Alfred A. Chambers), presented on the next page, are additions to the series originally contained in the memoir by Messrs. Clarke and Wheeler, referred to on page 240 of this paper.

The specimen on shore, above high tide, line I, southeast reef, is composed of 80.1 per cent of fine gravel and 18.5 per cent of coarse sand, the two sizes aggregating 98.6 per cent of the sample. This specimen contains much basaltic gravel, as would be expected on the shore of a volcanic island. It is highly noteworthy that even 200 feet from shore on the southeast reef $SiO_2 + (Al, Fe)_2O_3$ together constitute only 0.63 per cent of the sample, showing that the volcanic material is not carried seaward in an appreciable amount. Reference to the quotation from Dr. Mayer's article (page 245) will give the explanation of the small percentage of these constituents.

The prevailing winds are from the southeast; the currents sheer around the island, and carry northwestward any material which has been sufficiently comminuted. Dr. Mayer mentions that lava boulders extend "fully 200 feet from mean low tide," but judging from the chemical analysis the fine

material is not incorporated in the sediments. As the mouth of Haddon Brook is west of the line along which the samples were taken, the detritus brought to the sea by it would be moved westward. Furthermore, as the rainfall on Murray Island is rather low, only 32.66 inches per year, according to information furnished me by Dr. Mayer, the quantity of terrigenous material washed into the sea may be small.

The specimen from line III, north end of the island, cast up on the reef, 1,700 feet from shore, differs from the samples taken from below water-level in having a large percentage of fine gravel (49.4 per cent) and in having more $MgCO_3$ (7.57 per cent). There may have been some secondary concentration of magnesia.

Analyses of Corallinaceæ from Murray Island and Cocos-Keeling Islands.

(By A. A. Chambers.)

Chemical analyses of calcareous algæ.			
	Goniolithon frutescens Fosl., Cocos-Keeling Islands.	Goniolithon orthoblastum (Heyd.) M. A. Howe, Murray Island, Australia.	Lithophyllum kaiseri Heyd., Cocos-Keeling, Islands.
Loss on ignition	46.70	50.97	45.72
$SiO_2+Fe_2O_3+Al_2O_3$	.07	.11	.28
CaO	46.16	42.39	45.92
MgO	6.29	5.71	7.09
P_2O_5	Present.	Present.	Present.
SO_3	None.	None.	None.
Total	99.22	99.18	99.01
CO_2 needed	43.19	39.59	43.88
Reduced analyses (hypothetical combinations).			
SiO_2, $(Al, Fe)_2O_3$	0.07	0.12	0.29
$MgCO_3$	13.80	13.66	15.33
$CaCO_3$	86.13	86.22	84.38
$Ca_3P_2O_8$	Trace.	Trace.	Trace.
$CaSO_4$	.00	.00	.00
Total	100.00	100.00	100.00

The specimen of limestone from 500 to 700 feet above sea-level is indurated, light yellowish-gray in color, somewhat horny in texture, with a conchoidal fracture. It is largely coral, with numbers of embedded foraminifera, of which Miliolidæ are the most noticeable in a thin section. The chemical analysis shows it to be 98.97 per cent $CaCO_3$, a remarkably pure limestone. As the percentage of $MgCO_3$ is only 0.60 per cent, there has been no dolomitization of this specimen, at least. This is coral-reef rock. Analyses of other specimens would probably show more $MgCO_3$, as a few fragments of Lithothamnion or a few foraminifera would increase its percentage. Haddon, Sollas, and Cole report that "analysis shows a fragment from the summit of Gilam to be largely dolomitic."[1]

[1]Trans. Roy. Irish Acad., vol. 30, p. 433, 1894.

SUMMARY ON THE MURRAY ISLAND SAMPLES.

(1) The mechanical analyses show two classes, or grades, of deposits: (*a*) beach deposits, subject to wave-action at or above high-tide level. Fine gravel (1 to 2 mm. in diameter) constitutes from 50 to 80 per cent of the deposit; fine gravel and coarse sand combined range from a little more than 80 per cent up to nearly 99 per cent of the material; (*b*) sands between the reef and the shore, in which coarse gravel is from 35 to about 66 per cent of the material. Class (*b*) shows increase in percentage of medium and fine sand as the shore is approached until 600 feet offshore; at 200 feet from shore there is increase in the amount of fine gravel. In this class there is a larger percentage of coarse sand than of any other size. The small percentage of silt and clay is attributed to outwash by currents.

(2) The $MgCO_3$[1] content averages 5.745 per cent in the samples behind the reef. The relative importance of organisms 1,600 feet from shore is as follows: (*a*) corals, 41.9 per cent; (*b*) calcareous algæ, 32.6 per cent; (*c*) foraminifera, 12.4 per cent; mollusca, 10.2 per cent. At 200 feet from shore the order is: calcareous algæ, 42.5; corals, 34.6 per cent; mollusca, 15.2 per cent; foraminifera, 4.1 per cent. The investigation of Dr. Goldman shows the possibility of correlating the chemical composition of an entire sample with the chemical composition of its different constituents.

(3) The higher percentage of magnesia in the specimen washed up on the reef off the north end of the island may be due to secondary concentration. This subject needs further investigation.

COMPOSITION OF TWO MURRAY ISLAND BOTTOM SAMPLES ACCORDING TO SOURCE OF MATERIAL.[2]

The following are the results of an attempt to determine the group of organisms to which each grain in two different samples of "coral" sand belonged and to explain the chemical composition of the sands as determined by direct chemical analysis; especially to account for the relative amounts of calcium carbonate and magnesium carbonate. As far as possible, each of a lot of grains was identified either by its external characters or by its internal structure as revealed under the microscope. In this process, as many of the grains had to be destroyed, the weight of grains of each kind had to be calculated from the weight of those preserved. This proved more difficult than had been anticipated. From these weights the proportion of the leading chemical constituents present was calculated by using figures for the composition of each organism, obtained (by the courtesy of Dr. F. W. Clarke) from the manuscript of a paper by Clarke and Wheeler on the composition of the inorganic constituents of marine invertebrates and calcareous algæ. From the composition thus computed for each group of organisms the composition of the entire sand was calculated.

[1]Hypothetical combination. [2]The discussion of this topic is contributed by Dr. Marcus Isaac Goldman.

The count was based on the differentiation of the following groups of organisms:

Madreporarian corals.	Echinoids.	Alcyonarian corals.
Mollusks.	Worm-tubes.	Bryozoa.
Calcareous algæ.	Crustacea.	Millepores.
Foraminifera.		

Wherever possible, further subdivisions, almost entirely by external characters, were made as follows:

Mollusks: Gastropods, Pelecypods, Scaphopods.
Foraminifera: Tinoporus baculatus, Amphistegina lessoni, Orbitolites.
Crustacea: Balanus or other barnacles (cirripeds), Malacostraca (crabs, lobsters, etc.), Ostracods.
Alcyonaria: Spicules, solid skeleton.
Echinoids: Spines, plates.

The recognition of the microscopic characters was based on a preliminary study of known material from the different groups, in thin section and more especially as crushed fragments. It is in the study of known material that the work needs particularly to be enlarged, for while the groups differentiated do undoubtedly have certain persistent characters, yet one constantly learns, in studying new, known material in a group, that the differences between members of a group are often more apparent than the resemblances; consequently, grains are occasionally encountered in the unknown material, all the most individual characters of which are unfamiliar, or characters are combined that seem to ally them to different groups—groups perhaps as remote from each other as algæ and crustaceans. The remedy for this confusion is, of course, to study a greater variety of known material under each group; in fact, the most satisfactory procedure would be to collect, at the same time that the sample of sand is collected, a specimen of the skeleton of every species inhabiting the neighborhood of the sample. Then, too, a more detailed and careful study of the materials should be made than the time available in preparation for the study here presented permitted.

In spite of the difficulties that many of the grains offered, it was deemed best to assign each of them to some form, since a majority of the doubtful grains will probably be correctly identified and the right result consequently more nearly approached than by leaving them unidentified and thus with no effect on the result. Accordingly, only two or three grains, all of one kind and resembling nothing that was known to me, were left undetermined.

In order to enable the reader to estimate the probability of accuracy in the results here presented, it will be well to indicate in a general way the ease or difficulty with which the groups were differentiated. One of the most important differentiations is that between corals and algæ, and this, fortunately, is one of the easiest and surest. But within each of these groups are two subgroups of very distinct chemical composition. The corals contain the madreporarians (which are nearly pure lime) and the alcyonarians, which

(in addition to predominant $CaCO_3$) have about 15 per cent $MgCO_3$ and 8 per cent $Ca_3P_2O_8$. While the loose spicules, which are probably by far the most abundant skeletal representative of the alcyonarians, are easily recognized by their external form, the laminated solid skeleton of such forms as *Lepidisis* and *Isis* have characters very much like the madreporarian skeleton; the loose spicules, too, when their external form has been lost by wear, are not readily differentiated. Fortunately, the alcyonarians seem scarcely to be included in the materials studied from Murray Island. In the two samples only one spicule was noticed. Where spicules are so scarce it is improbable that there is an appreciable amount of the solid skeleton present and the failure to recognize any alcyonarian material may therefore have been justified. In the first examination of some of the portions a number of grains were tentatively classified as alcyonarian, but on re-examination the characters suggesting this group did not seem pronounced enough, in the absence of any evidence that the group was appreciably represented, to justify leaving them there. They were therefore placed with the madreporarians, which they resembled in their general characters.

The two distinct chemical groups in the algæ are the Corallinaceæ and the genus *Halimeda*. The Corallinaceæ that have been analyzed contain about 19 per cent of $MgCO_3$, *Halimeda* only about 0.5 per cent. This chemical difference was learned too late for the differentiation of the two groups in the study of the Murray Island sands; but it is very doubtful in any case whether such differentiation was possible except in the coarsest sizes of material. However, here is a question requiring the most careful attention and persistent effort, for both groups are well represented in the sands and the difference in their content of magnesium carbonate, the substance with which this study is most concerned, far exceeds that between the members of any other group considered.

Mollusks are one of the groups having generally the best-defined characters under the microscope. They tend a little at times to confusion with crushed madreporarian material; but, even if the two are occasionally not properly discriminated, it is not important from the chemical point of view, since both are nearly pure $CaCO_3$.

Foraminifera, at least those present in the Murray Island sands, are more often recognizable by their external characters than any other group. Under the microscope, too, the small perforations of the Perforata are unmistakable, but the Imperforata are a little more difficult, since they tend to resemble certain fragments of algæ or bryozoa.

Bryozoa were probably very scarce, if at all present. Their microscopic characters seem to be rather mixed, partly resembling corals, partly perhaps algæ, but recognition by external character would probably be possible with a large proportion of bryozoan grains.

Echinoid fragments are by far the most easily recognized under the microscope, by their reticulation in three planes and the curved, sharply

defined outlines of the individual fragments of this structure, as also by the fact that each plate is apparently always a single crystal, extinguishing, as a consequence, simultaneously between crossed Nicol prisms.

Crustacea are characterized particularly by a vaguely fibrous structure, which tends, however, to be confused with a more pronounced fibrous structure in certain algal fragments. Not much familiarity with the group was acquired. Where cirripeds or ostracods have been differentiated from other crustacea it was by external characters.

Worm-tubes were recognized only by external form. Their microscopic characters seemed difficult to recognize, especially because the samples of known material generally contained, inside the tube, fragments of a number of other organisms, which after crushing appeared on the slide mixed with the fragments of the tube itself.

Characters for differentiating millepores from madrepores under the microscope were not worked out. On inspection they appeared extremely similar. It seemed, however, as though millepores if present should be recognizable externally by their cellular structures, even in very small grains.

The manipulation of the count varied somewhat in different sizes. Some effort was made to keep a proportion between the number of grains determined in the particular size-portion and the ratio that the portion bore to the entire sand, but to have kept the ratio at all exact would have necessitated counting more grains in the coarser portions or fewer in the fine than would be worth while, so that the ratio maintained was only rough. In the coarser portions the weight as well as the number of grains taken for identification was determined—except in the "fine gravel" of No. 27353*a*, which was the first studied, before the importance of determining the weight was recognized. The object, then, was to preserve from the weighed portions a large number of the original grains of each group and from their weight to calculate the weight of the total of grains of each group originally present, in such a way as to check with the original weight.

The method of calculating the weights of these portions will be presented later. At present the method of determining the number of different kinds of grains is to be described. As finally developed, it consisted in identifying as many grains as possible directly by their external appearance. These were put aside in small vials. It was found that this identification could be best conducted by grouping the grains that appeared to be most alike in color, texture, translucency, form, etc. By identifying a certain number of these from their internal structure under the microscope the identification, by external appearance, of those most closely resembling them was assured. It was found that generally the algæ were most certainly recognized by a certain rough, porous, opaque appearance. For determining the microscopic character the effort was made, as often as possible, to take only part of the grain. This on the one hand gives identified grains for future comparison and on the other gives more material for weighing. In order to get the true

weight, however, it was necessary to know the fraction of the original grain that the portion preserved represented. This was estimated and recorded.

The slides of crushed grains or portions of grains were in the end prepared directly with a rather thin solution of Canada balsam in xylol. In this way slides that were interesting or difficult could be kept for future study.

With the fine and very fine sand the procedure developed was to lay out, in more or less accurate alinement, an indefinite number of grains taken from all parts of the sample. From one end of this row a suitable number of grains was then taken in the order in which they lay. This was done because it was found difficult to keep track of a definite number of these fine grains taken in advance, because the method was quicker, and because the original weight of the grains taken was too small to be worth determining.

The ratios of numbers of grains of different groups had to be converted into ratios of weights of the groups because of apparent difference in weight per unit volume; but to arrive at any accurate figures for these relative weights proved very difficult. In one portion the unit weight of mollusk grains would greatly exceed that of madrepores, in others the reverse. The difficulty lay mainly in the fact that the grains were very variable in size and that those identified by their external appearance or by removing a fraction for microscopic study tended to be the larger ones. Consequently their average weight could not be taken as the average weight of all the grains of that group originally present. Under these circumstances, with the small amount of data available, any attempt at a strictly mathematical determination of probable unit weights seemed inapplicable. It seemed best to adjust the weights of the coarser portion on the basis of general considerations derived partly from the portion itself and partly from portions previously studied. In one case the first assumptions led to a total weight for the grains studied which differed only 8 mg. in 383 mg. from the weight originally determined. In another case 4 trials had to be made, adjusting the assumptions in each case, before a sufficient correspondence was obtained.

For the portions finer than the coarse sand ratios of weight units were calculated from the results arrived at in the previous calculations. The important factors were the relative weights of algæ, corals, and mollusks. Since there were no observed unit weights to go by in these finer portions, much greater generalization of the results was necessary. The unit weights of corals and mollusks were therefore taken as equal. The actual adjustment was made in the "fine gravel" of No. 27337. Since large quantities were weighed in that portion, observations were careful and full, and the unit weights obtained seemed better balanced than in any other portion. The unit weight of coral and mollusk was taken at a round figure about the mean of the weights of each group in this portion and all other figures were kept in their original ratio. From these relative unit weights the relative weights of the total number of grains of each group present in a portion were calculated and from these the percentage by weight of each group was obtained.

In future it would be well to seek more direct and accurate results by some method like the following: Select from the sample laid out for determination some grain of fairly regular shape to be regarded as a unit of volume; then estimate and record for each grain studied the number of such units it contains. In this way there will be a record of the number of units of volume of each organic group originally present and thus direct comparisons of unit weights will be possible as far as the volumes were correctly estimated. In any case this will be more accurate than merely recording the number of grains of each group. Where part of a grain is taken for crushing and microscopic study, both the number of units of volume it originally contained and the number of units preserved for weighing must be recorded. Probably it will be best to take one of the smaller grains, though not necessarily the smallest, as the unit; or perhaps some more regular unit (as a piece of shot passing the same sieve as the sample) will be found best.

Chemical Composition.

The chemical composition of each size portion was obtained by calculating the percentage of the four principal salts, $CaCO_3$, $MgCO_3$, $CaSO_4$, and $Ca_3P_2O_8$, contained in each organic group. The assumed composition of the organic groups was derived from figures given in the manuscript of Dr. Clarke and Mr. Wheeler's unpublished paper.[1] Those used in the calculations for this paper are tabulated herewith:[2]

	$CaCO_3$	$MgCO_3$	$CaSO_4$	$Ca_3P_2O_8$
Corallinaceæ	80.00	19.00	1.00	......
Halimeda	99.00	.50	.50	......
Mean alga	89.50	9.75	.75	......
Madreporaria	99.30	.70	......	......
Alcyonaria	75.00	15.00	......	8.00
Mollusks	99.75	.25	......	......
Tinoporus	89.00	11.00	......	......
Amphistegina	95.20	4.80	......	......
Orbitolites	89.40	10.60	......	......
Polytrema	88.75	11.25	......	......
Approximate average foraminifera	89.50	10.50	......	......
Crustacea:				
(1) Malacostraca and ostracods	77.00	12.50	1.25	8.75
(2) Balanus	98.50	1.50	......	......
Sea-urchin spines	90.00	9.00	1.00	......
Worm-tubes	91.00	8.00	......	1.00

In a few cases of individual species of foraminifera, etc., these figures could be taken directly; but in most cases some sort of compromise, which was not at all a mathematical averaging, had to be made. The reason for not taking an average was mainly that many forms show a tendency to an increased percentage of $MgCO_3$ with increase in temperature of the water in which they live; hence forms from environments corresponding more or less to Murray Island had to be favored in deriving the figures. Further-

[1]F. W. Clarke and W. C. Wheeler. The inorganic constituents of marine invertebrates and calcareous algæ.

[2]The combinations of acid and basic radicals in all the following tables are hypothetical and are used in order to conform with those given in Clarke and Wheeler's manuscript.

more, SiO_2 and $(Al, Fe)_2O_3$ were rejected as being probably extraneous impurities, very variable and generally very small in amount. The value used for the composition of the algæ as given in the preceding table is an approximate mean of the composition of Corallinaceæ and *Halimeda*.

The following tables give the essential portions of the results obtained:

Analysis of sample No. 27353a, line I, 1,600 feet from shore.

	No. of grains present.	Calculated weight.	Weight percentage.	Calculated percentage composition.			
				$CaCO_3$	$MgCO_3$	$CaSO_4$	$Ca_3P_2O_8$
1. FINE GRAVEL.		*gm.*					
Algæ	44	0.0582	34.45	30.85	3.35	0.25	......
Corals	16	.0191	11.30	11.20	.10	......	......
Mollusks	16	.0219	12.95	12.90	.05	......	......
Tinoporus baculatus	51	.0449	26.60	23.70	2.90	......	......
Amphistegina lessoni	25	.0175	10.35	9.85	.50	......	......
Orbitolites	2	.0028	1.65	1.50	.15	......	......
Barnacles (Balanus?)	2	.0036	2.10	2.05	.05	......	......
Echinoid spine	1	.0010	.60	.55	.05	Tr.	......
	157	.1690	100.00	92.60	7.15	.25	......
2. COARSE SAND.							
Algæ	27	0.0094	34.30	30.70	3.35	0.25	......
Corals	66	.0145	52.95	52.60	.35	......	......
Mollusks	11	.0027	9.85	9.80	.05	......	......
Tinoporus	2	.0004	1.45	1.30	.15	......	......
Amphistegina	3	.0003	1.10	1.05	.05	......	......
Polytrema	1	.0001	.35	.30	.05	......	......
	110	.0274	100.00	95.75	4.00	.25	......
3. MEDIUM SAND.		*wt. units*					
Algæ	3	435	10.75	9.60	1.05	0.10	......
Corals	26	3,380	83.50	82.90	.60	......	......
Mollusks	1	100	2.50	3.20	.05	......	......
Foraminifera	1	130	3.25	2.25	.25	......	......
	31	4,045	100.00	97.95	2.95	.10	......
4. FINE SAND.							
Algæ	4	580	22.15	19.85	2.15	0.15	......
Corals	11	1,430	54.55	54.15	.40	......	......
Mollusks	4	520	19.85	19.80	.05	......	......
Ostracods	1	90	3.45	2.65	.45	.05	0.30
	[1]20	2,620	100.00	96.45	3.05	.20	.30
5. VERY FINE SAND.							
Algæ	1	145	8.00	7.15	0.80	0.05	......
Corals	7	910	49.80	49.45	.35	......	......
Mollusks	2	260	14.25	14.20	.05	......	......
Foraminifera	3	300	16.45	14.70	1.75	......	......
Ostracod	1	90	4.95	3.80	.65	.05	0.45
Coccolithophoridæ[2]	1	[3]120	6.55	5.85	.65	.05	......
Clay	3	([4])	......	......	......	......	......
	18	1,825	100.00	95.15	4.25	.15	.45

[1]Compound grains (4) regarded as proportionate mixture of other materials present and therefore ignored.
[2]Assume same chemical composition as other calcareous algæ.
[3]Estimated. [4]Ignore. SiO_2 and $(Al, Fe)_2O_3$ are not being calculated in the chemical composition.

Summaries, sample No. 27353a.

	Algæ.	Corals.	Mollusks.	Tinoporus.	Amphistegina.	Orbitolites.	Polytrema.	Undifferentiated foraminifera.	Barnacles.	Ostracods.	Coccolithophoridæ.	Echinoids.	Total.
I. Numbers of grains of different organisms counted.													
Fine gravel	44	16	16	51	25	2	...	...	2	...	...	1	157
Coarse sand	27	66	11	2	3	...	1	...	...	...	...	...	100
Medium sand	3	26	1	...	...	...	...	1	...	...	...	...	31
Fine sand	4	11	4	...	...	...	...	...	...	1	...	...	20
Very fine sand	1	7	2	...	...	...	...	3	...	1	1	...	15
Total	79	126	34	53	28	2	1	4	2	2	1	1	333
II. Calculated percentages by weight of different organisms present.													
Fine gravel	9.3	3.1	3.5	7.2	2.8	0.4	...	...	0.6	...	...	0.2	...
Coarse sand	22.7	35.1	6.5	1.0	.7	...	0.2	...	...	...	...	...	...
Medium sand	.5	3.3	.1	...	...	...	...	0.1	...	...	...	...	...
Fine sand	.1	.3	.1	...	...	...	...	...	...	Tr.	...	...	...
Very fine sand	...	.1	...	...	...	...	...	...	...	...	Tr.	...	...
Total	32.6	41.9	10.2	8.2	3.5	.4	.2	.1	.6	Tr.	Tr.	.2	97.9
III. Calculated percentage chemical composition by organisms.													
$CaCO_3$	29.2	41.6	10.2	7.3	3.3	0.4	0.2	0.1	0.6	...	...	0.2	93.1
$MgCO_3$	3.2	.3	...	.9	.2	...	...	...	...	...	...	...	4.6
$CaSO_4$	.2	...	...	...	...	...	...	...	...	...	...	...	.2
$Ca_3P_2O_8$	...	...	...	...	...	...	...	...	...	Tr.	...	...	Tr.

IV. Calculated percentage chemical composition by size portions.

	Per cent present.	Per cent of constituents.			
		$CaCO_3$	$MgCO_3$	$CaSO_4$	$Ca_3P_2O_8$
Fine gravel	27.1	25.2	1.9	Tr.	...
Coarse sand	66.2	63.4	2.6	0.2	...
Medium sand	4.0	3.9	.1	Tr.	...
Fine sand	.5	.5	Tr.	Tr.	Tr.
Very fine sand	.1	.1	Tr.	Tr.	Tr.
	97.9	93.1	4.6	.2	...
Silt	.3	[1].3	Tr.	...	...
Clay	1.4	[1].9	Tr.	...	...
Total	99.6	94.3	4.6	.2	...

[1]See discussion following.

In the portions of silt and clay size the particles were too fine for quantitative identification, although a number of them could be recognized. Following are brief notes of a qualitative examination.

Silt (sample No. 27353a).—Of the larger fragments very many are foraminifera; coccolithophoridæ (*Pontosphæra*) are fairly frequent; spicules are scarce and are mainly siliceous.

Clay (sample No. 27353a).—Coccoliths are extremely rare. There are flakes with needle-shaped or lath-shaped, highly birefringent inclusions. These inclusions, according to Dr. H. E. Merwin, of the Geophysical Labora-

Analyses of sample No. 27337, line I, 200 feet from shore.

	No. of grains present.	Calculated weight.	Weight percentage.	Calculated percentage composition.			
				$CaCO_3$	$MgCO_3$	$CaSO_4$	$Ca_3P_2O_8$
1. FINE GRAVEL.		*gm.*					
Algæ	39	0.0569	39.75	35.60	3.85	0.30	......
Corals	31	.0383	26.75	26.55	.20	......	......
Mollusks	29	.0392	27.40	27.30	.10	......	......
Tinoporus	5	.0049	3.40	3.05	.35	......	......
Amphistegina	4	.0029	2.00	1.90	.10	......	......
Orbitolites	2	.0010	.70	.65	.05	......	......
Total	110	.1432	100.00	95.05	4.65	.30	......
2. COARSE SAND.							
Algæ	56	0.0195	50.90	45.60	4.95	0.35	......
Corals	58	.0135	35.25	35.00	.25	......	......
Mollusks	20	.0034	8.90	8.85	.05	......	......
Tinoporus	2	.0004	1.05	.95	.10	......	......
Amphistegina	1	.0001	.25	.25	Tr.	......	......
Orbitolites	1	.0003	.80	.70	.10	......	......
Foraminifera (undifferentiated)	3	.0006	1.55	1.40	.15	......	......
Crustacea	2	.0004	1.05	.80	.15	Tr.	0.10
Worm-tubes	1	.0001	.25	.25	Tr.	......	Tr.
Total	144	.0383	100.00	93.80	5.75	.35	.10
3. MEDIUM SAND.		*wt. units.*					
Algæ	11	1,595	31.05	27.80	3.00	0.25	......
Corals	20	2,600	50.65	50.30	.35	......	......
Mollusks	5	650	12.65	12.60	.05	......	......
Foraminifera (undifferentiated)	1	100	1.95	1.75	.20	......	......
Orbitolites	1	130	2.55	2.30	.25	......	......
Worm-tube	1	60	1.15	1.05	.10	......	Tr.
Total	39	5,135	100.00	95.80	3.95	.25	Tr.
4. FINE SAND.							
Algæ	21	3,045	42.40	37.95	4.15	0.30	......
Corals	20	2,600	36.20	35.95	.25	......	......
Mollusks	9	1,170	16.30	16.25	.05	......	......
Foraminifera	2	200	2.75	2.45	.30	......	......
Balanus	1	170	2.35	2.30	.05	.30	......
Total	53	7,185	100.00	94.95	4.75	.60	......
5. VERY FINE SAND.							
Algæ	6	870	34.00	30.45	3.30	0.25	......
Corals	11	1,430	55.85	55.45	.40	......	......
Mollusks	2	260	10.15	10.15	Tr.	......	......
Total	19	2,560	100.00	96.05	3.70	.25	......

tory of the Carnegie Institution of Washington, are "hexagonal plates set edgewise. They are optically positive, ω = about 1.535, ϵ = about 1.560. These are surely not aragonite, but I can find in the mineral tables nothing corresponding to them."[1] They require further study.

Summaries, sample No. 27337.

I. Numbers of grains of different organisms counted.

	Algæ.	Corals.	Mollusks.	Tinoporus.	Amphistegina.	Orbitolites.	Undifferentiated foraminifera.	Crustacea.	Balanus.	Worm-tubes.	Total.
Fine gravel	39	31	29	5	4	2	..	..	..	..	110
Coarse sand	56	58	20	2	1	1	3	2	..	1	144
Medium sand	11	20	5	..	..	1	1	..	..	1	39
Fine sand	21	20	9	..	..	..	2	..	1	..	53
Very fine sand	6	11	2	..	..	..	..	..	..	..	19
Total	133	140	65	7	5	4	6	2	1	2	365
II. Calculated percentage by weight of different organisms present.											
Fine gravel	9.4	6.3	6.5	0.8	0.5	0.2	...	...	...	...	....
Coarse sand	19.3	13.3	3.3	.4	.1	.3	0.6	0.4	...	0.1	....
Medium sand	3.8	6.2	1.5	...	...	.3	.2	...	...	.1	....
Fine sand	9.8	8.4	3.8	...	...	...	.7	...	0.6	...	....
Very fine sand	.2	.4	.1	...	...	...	...	...	...	...	....
Total	42.5	34.6	15.2	1.2	.6	.8	1.5	.4	.6	.2	97.6
III. Calculated percentage chemical composition by organisms.											
$CaCO_3$	38.0	34.4	15.2	1.0	0.6	0.7	1.3	0.3	0.6	0.2	92.3
$MgCO_3$	4.2	.2	.0	.2	.0	.1	.2	.1	.0	.0	5.0
$CaSO_4$	.3	....	....	...	...	...	...	...	...	...	.3
$Ca_3P_2O_8$	....	....	....	...	...	...	...	...	...	...	....

IV. Calculated percentage chemical composition by size portions.

	Per cent present.	$CaCO_3$.	$MgCO_3$.	$CaSO_4$.	$Ca_3P_2O_8$.
Fine gravel	23.6	22.40	1.10	0.3	..
Coarse sand	37.9	35.55	2.20	...	Tr.
Medium sand	12.2	11.70	.50	...	Tr.
Fine sand	23.2	22.00	1.15	...	..
Very fine sand	.7	.65	.05	...	..
	97.6	92.3	5.00	0.3	Tr.
Silt	.7	[2].7	Tr.	...	..
Clay	1.2	[2].7	Tr.	...	..
Total	99.5	93.7	5.0	0.3	..

Silt (sample No. 27337).—Contains coccolithophoridæ (*Pontosphæra*), minute foraminifera, sponge spicules, etc.

Clay (sample No. 27337).—In this clay round coccoliths are abundant; "there are numerous calcite grains and rhombs which appear exactly like

[1]Letter of May 9, 1916, from Dr. H. E. Merwin. [2]See discussion following.

chemical precipitates, also [unidentified] material such as described for [the clay of] sample 27353*a*."[1] In regard to the calcite grains it should be noted that they considerably exceeded in diameter the maximum diameter of the "clay" portion. It must be concluded, therefore, that they were not originally present in the sample, but were precipitated in evaporating down the water in which the "clay" was suspended. The "clays" of two other samples from the same region were examined and like sample No. 27353*a* were not found to contain any precipitated calcite.

Before comparing the results of the final summary with the direct analysis of the sample, some allowance must be made for the contents of the silt and clay. Trustworthy indication as to the probable composition of these portions is lacking, but their amount is so small that unless some great divergence from the composition of the other portions were indicated, the effect in changing the ratio of Ca to Mg in the total sample would not be appreciable in any case.

Analyses of sample No. 27353a, line I, 1,600 feet from shore.

	Ratio $CaCO_3$: $MgCO_3$.	Ratio Ca : Mg organisms.[1]	
		Relative weights.	Weight ratio.
Fine gravel......	100 : 7.57	24.25 : 73.05	100 : 301
Coarse sand.....	100 : 4.09	62.80 : 37.20	100 : 59.3
Medium sand....	100 : 2.56	86.00 : 14.00	100 : 16.3
Fine sand.......	100 : 3.16	74.40 : 22.15	100 : 29.8
Very fine sand....	100 : 4.47	64.05 : 31.00[2]	100 : 48.4
Silt.............	....	....	....
Clay............	....	....	....

[1]Ca organisms = Corals and mollusks; Mg organisms = Algæ and foraminifera.
[2]Includes coccolithophoridæ (*Pontosphæra*).

The foregoing table indicates a tendency for the proportion of magnesia to increase in the finer portions, and this may continue into the silt; but whether it also continues into the clay is very uncertain. The assumption that it is carried into the silt is supported by the apparent abundance of foraminifera in this portion, which is in conformity with their relative increase in the very fine sand; but what effect the increasing abundance of coccolithophoridæ has on the chemical composition is not known, since these forms have not been segregated and analyzed. It has merely been assumed that they have a composition similar to the algæ; but, in any case, the amount of silt is so small that all of it must undoubtedly be thrown to the $CaCO_3$. In the "clay" the proportion of the coccolithophoridæ appears even greater; then, too, the undetermined mineral ingredient and probably other indeterminate factors enter, so that the factors controlling the composition of this portion are of an entirely new sort. Furthermore, it seems proper to place nearly all the SiO_2 and $(Al, Fe)_2O_3$ into this portion, though a small part is undoubtedly present in the other portions. Charge say 0.5 per cent out of

[1]Letter of May 1916, from Dr. H. E. Merwin.

the total 0.6 per cent SiO_2 and $(Al, Fe)_2O_3$ to the "clay." That leaves 0.9 per cent "clay" to account for. Then assuming a composition of 96 per cent $CaCO_3$ and 4 per cent $MgCO_3$ the percentage of $MgCO_3$ becomes 0.046 or less than is being considered here. Comparing the calculated and directly determined results then we have, for sample No. 27353*a:*

	$CaCO_3$.	$MgCO_3$.	$CaSO_4$.	$Ca_3P_2O_8$	SiO_2 and $(AlFe)_2O_3$.
Calculated.....	94.3	4.6	0.2	Tr.	.60
Observed......	93.6	5.8	Tr.	..	.60

Following a similar procedure with sample No. 27337, line I, 200 feet from shore, we have:

	Ratio $CaCO_3$: $MgCO_3$.	Ratio Ca : Mg organisms.[1]	
		Relative weights.	Weight ratio.
Fine gravel......	100 : 4.90	54.15 : 45.85	100 : 84.70
Coarse sand.....	100 : 6.20	44.15 : 54.55	100 : 123.50
Medium sand....	100 : 4.28	63.30 : 35.55	100 : 56.15
Fine sand.......	100 : 4.98	52.50 : 45.15	100 : 86.10
Very fine sand....	100 : 3.85	66.00 : 34.00	100 : 51.50

[1]Ca organisms = Corals and mollusks; Mg organisms = Algæ and foraminifera.

Here there is even less system and therefore less basis for assumptions as to the probable value of the $CaCO_3 : MgCO_3$ ratio in the silt and clay. Foraminifera seemed abundant in the silt, but there is not in this sample, as there was in No. 27353*a*, any indication of a tendency in the fine sand towards their increase. Making the same assumptions as in No. 27353*a*, we have (deducting 0.50 per cent out of the 0.63 per cent of SiO_2 and $(Al, Fe)_2O_3$) 0.7 per cent "clay" to account for. Again, if we take $CaCO_3$ at 96 per cent of the silt and the "clay," the residue referable to $MgCO_3$ becomes negligible. The totals compared then are as follows, for sample No. 27337:

	$CaCO_3$.	$MgCO_3$.	$CaSO_4$.	$Ca_3P_2O_8$	SiO_2 and $(Al, Fe)_2O_3$.
Calculated.....	93.7	5.0	0.3	Tr.	0.63
Observed......	93.85	5.5	Tr.	.00	.63

Considering the results for both samples together, we see at once that in No. 27337 there is a much closer agreement between calculated and directly derived results than in No. 27353*a*. I do not know the explanation of this. Undoubtedly by far the largest part of the discrepancy in both cases is due to error in the assumed proportion of Corallinaceæ to *Halimeda*—that is to say, the Corallinaceæ are usually more than half of the algæ. I do not believe that the greater experience brought to the study of No. 27337 is adequate to account for an appreciable part of the greater agreement of the two results in this portion. It is much more probable that the ratio of the two types of algæ to each other was more nearly the assumed ratio, that is, in this nearer

shore area *Halimeda* was relatively more abundant than farther from the shore. The following calculations show the proportion in which the two types of algæ would have to be present in order to make the calculated and directly observed results for $MgCO_3$ agree. The results are not at all in conflict with what would be expected from field experience with coral reefs.

For sample No. 27353*a*, if the proportions of the two types of algæ were, Corallinaceæ 69.5 per cent, *Halimeda* 30.5 per cent, then there would be in the whole sample, Corallinaceæ 22.8 per cent, *Halimeda*, 9.8 per cent; and their respective contributions to the whole sample would be:

	$CaCO_3$.	$MgCO_3$.	$CaSO_4$.
Corallinaceæ	18.25	4.35	0.20
Halimeda	9.70	.05	.05
Revised calculations	27.95	4.40	.20
Original calculations	29.2	3.2	.20
Difference	−1.3	+1.2	....

Correcting the calculated results by these amounts, we have, for sample No. 27353*a*:

	$CaCO_3$.	$MgCO_3$.	$CaSO_4$.
Revised	93.0	5.8	0.2
Observed	93.6	5.8	Tr.

The fact that now the calculated amount of $CaCO_3$ has fallen below the observed amount proves that these revised calculations are not quite adequate to account for the discrepancies, though they bring about a closer agreement.

If in sample No. 27337 the Corallinaceæ were 57.05 per cent and *Halimeda* 42.95 per cent of the total algæ, then there would be in the whole sample Corallinaceæ 24.25 per cent, *Halimeda* 18.25 per cent, and their respective contributions to the whole sample would be:

	$CaCO_3$.	$MgCO_3$.	$CaSO_4$.
Corallinaceæ	19.35	4.65	0.25
Halimeda	18.10	.05	.05
Revised calculations	37.45	4.7	.30
Original calculations	38.0	4.2	.30
Difference	−0.55	+0.5	....

For the total of sample No. 27337, we then have:

	$CaCO_3$.	$MgCO_3$.	$CaSO_4$.
Revised	93.15	5.5	0.3
Observed	93.85	5.5	Tr.

Here the error in the calculated amount of $CaCO_3$ is increased, indicating that there is no consistent error running through the counts and calculations to explain all the discrepancies in chemical composition.

The discrepancy between the calculated and directly observed percentage of $CaSO_4$ in both samples is probably to be accounted for by greater solubility of the $CaSO_4$ than of the carbonates under the conditions in which they both exist in the sands. The sulphate in the calculated results is derived, as will be seen from the tables, almost entirely from the algæ. The determinations of the composition of algæ were made on fresh material, while the sands have lain for some time, in their disintegrated condition and free from their organic covering, in ocean water.

BOTTOM SAMPLES FROM THE BAHAMAS.

The Bahaman samples represent the following conditions:

(1) The area just behind the barrier reef off Cocoanut Point, Andros Island. These samples are Nos. 190 to 193. The general position of the area from which they were obtained is indicated on the small-scale map, plate 95, and the more precise position is shown on the map, figure 3.

(2) The finely divided mud accumulating in stagnant areas in South Bight. Sample No. 79, see plate 95.

(3) The finely divided, oolitic mud forming off the west end of South Bight. Sample No. 87, see plate 95.

(4) Shore material, subject to tidal overflow on the west side of Andros Island, near the mouth of South Bight. Sample No. 83, see plate 95.

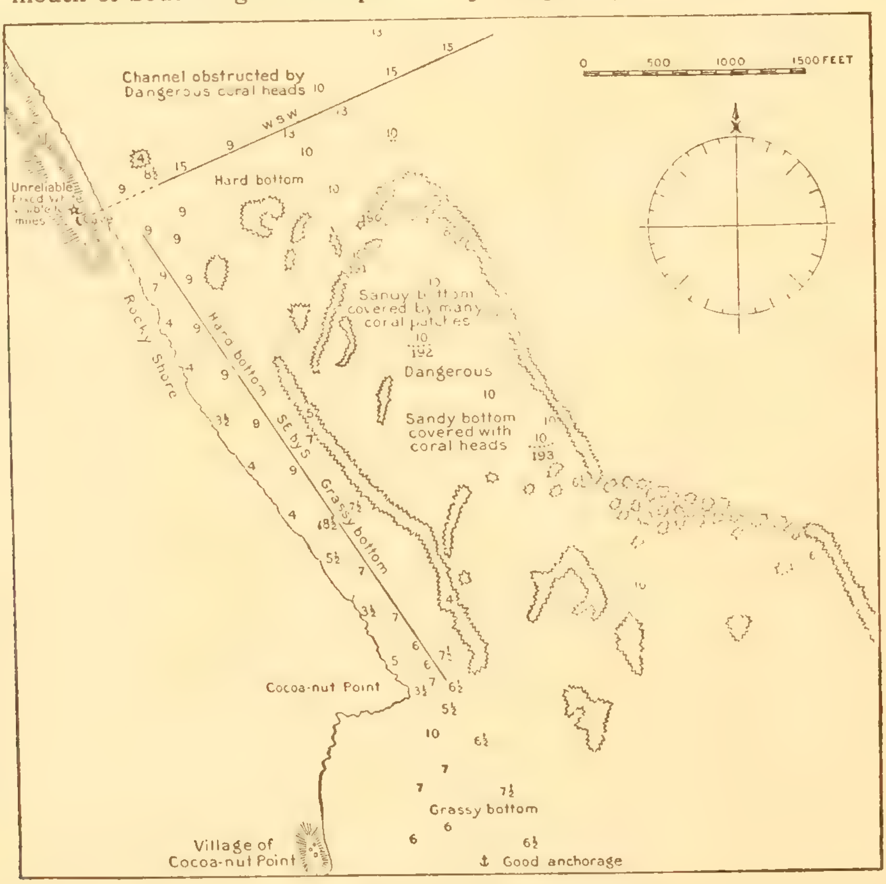
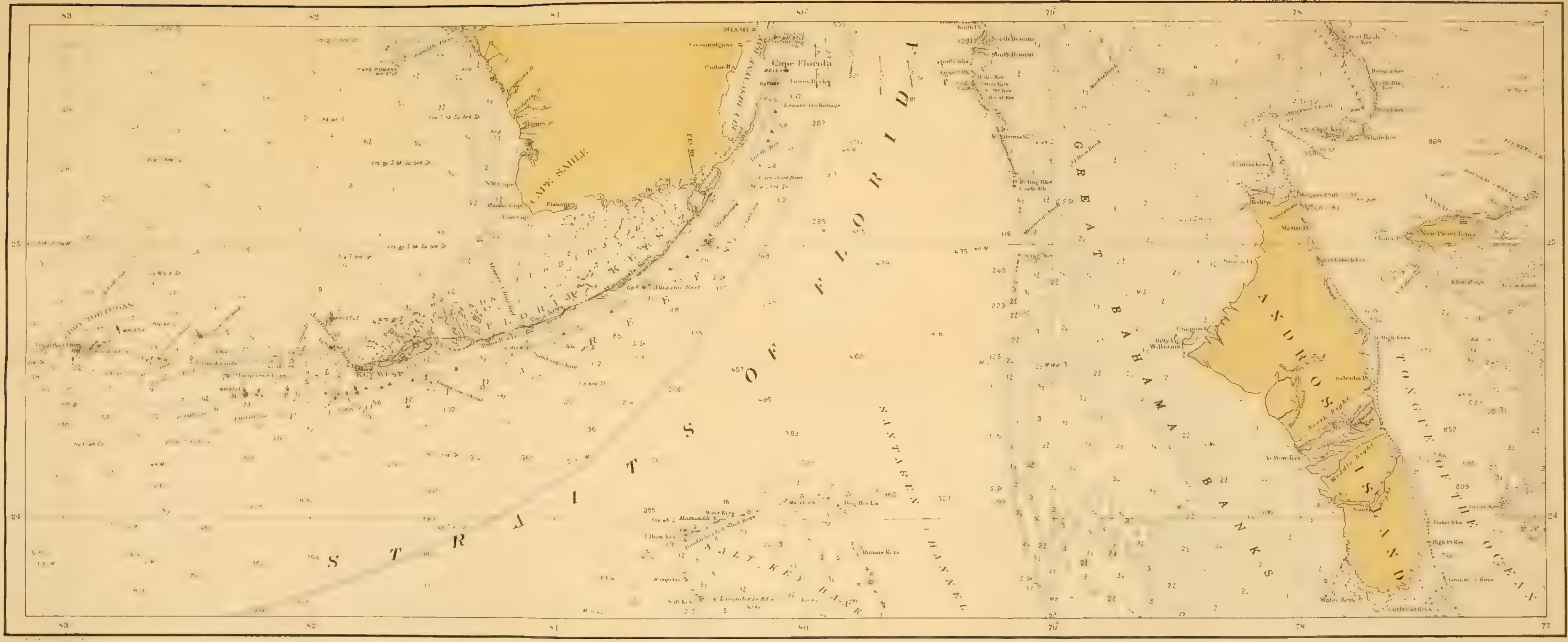


Fig. 3.—Map of Bethel Entrance, Andros Island, Bahamas.
Position of light, Lat. 25° 8″ N., Long. 78° 0′ 30″ W. From a plane-table survey by Alfred G. Mayer, May 1914.



MAP OF GREAT BAHAMA BANK AND SOUTHERN FLORIDA, SHOWING POSITION OF BOTTOM SAMPLE STATIONS

(Locations and their numbers shown in red)

(5) Oolitic sand from Great Bahama Bank, between Gun Cay Light and Northwest Passage, water about 9 feet deep. Sample No. 71, see plate 95.
(6) Globigerina ooze from depths of 825 fathoms (sample 84), and 800 to 820 fathoms (sample 85), see plate 95.
(7) Oolitic rock, from (*a*) Sharp Rock Point, Andros Island, marine-bedded oolite; (*b*) Queen's Stairway, Nassau, wind-blown oolite; (*c*) north ridge of Seven Hills, New Providence Island, wind-blown oolite.

SAMPLES FROM BEHIND THE REEF OFF COCOANUT POINT, EAST SIDE OF ANDROS ISLAND.

(Bottom samples 190–193; for precise location see fig. 3.)

Figure 3 shows the general relations of reefs to depths and kind of bottom. The country rock is oolite. The bottom material is composed mostly of calcareous algæ, foraminifera, fragments of madreporarian corals, alcyonarian spicules, and mollusk fragments. There are also some coccolithophoridæ, sponge spicules, echinoid fragments, and grains derived from the oolite which is exposed along shore and extends under sea. *Polytrema* and crustaceous calcareous algæ (*Lithothamnion æmulans* Foslie and Howe) are abundant here, as in Murray Islands. *Goniolithon strictum* Foslie is common in areas of quieter water.

The following are the results of mechanical analyses of the samples:

Mechanical analyses of bottom samples Nos. 190 to 193, from the Bahamas.[1]

[Graphic illustrations of the results of these analyses, plate 94.]

No., U. S. Bureau of Soils.	Field No. (of T. W. Vaughan).	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
27316	190	0.2	2.0	9.2	85.5	2.5	0.1	1.4
27317	191	2.8	13.5	27.7	53.2	1.2	.4	1.4
27318	192	6.9	29.5	29.2	31.9	.9	.6	1.1
27319	193	5.6	15.0	16.5	55.8	5.2	.7	1.2

[1]By the U. S. Bureau of Soils.

The following is a chemical analysis of a composite sample of all four samples, made by taking equal portions of each of the four and mixing them:

Chemical analysis of composite of samples 190 to 193 from behind reef off Cocoanut Point, Andros Island.

(By Alfred A. Chambers.)

Analysis.		Reduced.	
Constituent.	Per cent.	Constituent.	Per cent.
Loss on ignition	44.84	SiO_2	0.09
SiO_2	.09	$(Al, Fe)_2O_3$	.08
Fe_2O_3 Al_2O_3	.08	$MgCO_3$	5.24
CaO	51.56	$CaCO_3$	94.59
MgO	2.43	$Ca_3P_2O_8$	.00
P_2O_5	None	$CaSO_4$	Trace
SO_3	Trace		
Summation	99.00	Summation	100.00

Comparisons with Samples from Behind Murray Island Reef.

A comparison of both the mechanical and chemical analyses of the Murray Island material from the southeast reef, line I, at stations 200, 600, 1,200, and 1,600 feet from shore, with that from Cocoanut Point reveals close similarity. The following table shows the relative amounts of silt and clay in both localities:

Percentages of silt and clay in samples from Murray Island and Cocoanut Point.

Murray Island.		Cocoanut Point.		Remarks.
200 feet from shore......	1.9 p. ct.	Sample 190........	1.5 p. ct.	It should be noted that as fine and medium sand are predominant in the Cocoanut Point samples, they average finer than the Murray Island specimens.
600 feet from shore......	2.8	191........	1.8	
1,200 feet from shore......	.9	192....	1.7	
1,600 feet from shore......	1.4	193........	1.9	
Average.......... ...	1.75	Average.......	1.725	

The following table gives the relative amount of $MgCO_3$[1] in the two sets of bottom samples from behind Murray Island and Cocoanut Point reefs:

Percentages of $MgCO_3$ in samples from Murray Island and Cocoanut Point.

Murray Island.		Cocoanut Point.	
200 feet from shore......	5.52 p. ct.	Composite of samples 190 to 193...	5.24 p. ct.
600 feet from shore......	5.95		
1,200 feet from shore......	5.76		
1,600 feet from shore......	5.83		
Average.............	5.745	Average.......	5.24

The $MgCO_3$[1] is 0.505 per cent higher in the Murray Island sample, a difference of roughly 10 per cent, when the $MgCO_3$ ratio of the two samples is compared.

The estimates of the percentages of the different ingredients in the Cocoanut Point samples have not been completed, but it will be seen from the statements on page 263 that the agencies contributing to the bottom deposits in the two areas are similar, except that alcyonaria are more important in the Bahaman than in the Australian material. Another similarity should be indicated: Murray Island is south of the equator in the track of the southeast trade winds, while Cocoanut Point lies north of the equator near the northern limit of the northeast trades. In both areas the winds blow across the reef. The relations are such in both areas that currents induced by winds and tides tend to remove fine sediment and transport it to other areas. Therefore in these two areas, on nearly opposite sides of the earth, there are complexes of similar factors at work, which produce geologic results essentially identical.

[1]Hypothetical combination.

Precipitation of $CaCO_3$ in the Ocean and the Possibility of its Solution in the Sea.

In the foregoing paragraph I have expressed it as my opinion that the small percentage of particles of silt and clay size in both the Murray Island and Cocoanut Point samples is due to the washing away of the fine material—that is, to mechanical sorting. The only other possible explanation is that its removal is due to solution by sea-water. The latter hypothesis will be briefly discussed.

My personal experience with the problem of the chemical precipitation of $CaCO_3$ from sea-water and the consideration of the reverse of the process of precipitation, that of solution of $CaCO_3$ by sea-water, began in the winter of 1907–08, when I first examined the exposures of the oolitic limestones in the vicinity of Miami, Florida. There were associated in this work Messrs. Samuel Sanford, G. C. Matson, and F. G. Clapp. All of us agreed that the origin of the oolites could not be explained on the "wind-blown coral sand" hypothesis of Mr. A. Agassiz. Because the oolites are not of detrital origin, but are zonal in structure, showing outward growth from a central nucleus, and because embedded in them there are marine fossils which have not suffered notable attrition, we interpreted the deposits as marine formations due partly to chemical processes which we did not understand.[1] As it seemed to me that oolite might be found forming in the bays and sounds behind the Florida keys, I began in 1908, in connection with the Tortugas Laboratory, a systematic study of the shoal-water bottom deposits of southern Florida. The result of the first season's field work, in 1908, was stated in the following words:

> "In the shallow waters near the shore the opportunity for re-solution as the material settles to the bottom is not afforded and the accumulation on the sea bottom of large quantities of amorphous calcium carbonate apparently not of detrital orgin, is undeniable."[2]

Although an attempt was made to explain the precipitation of the $CaCO_3$ by suggesting processes whereby the CO_2 content of the water might be reduced (*op. cit.*, p. 135), it was said in the introduction (p. 106): "The chemical processes of precipitation have not been sufficiently studied." The work of Drew, 1911–12, extended by Kellerman after the former's unfortunate death, as it showed that denitrifying bacteria evolve ammonia, resulted in knowledge of one factor capable of producing precipitation of calcium carbonate from sea-water. But as will later be made evident, notwithstanding the great abundance of ammonifying bacteria, they are almost certainly not the only agents.

Prosecution of the study of the bottom deposits showed that in all areas not swept by relatively strong currents, fine sediment is accumulating, and that a considerable proportion of this material is a chemical precipitate (the

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[1] See Carnegie Inst. Wash. Pub. 133, pp. 173-177, 1910. [2] *Op. cit.*, p. 136.

result of either bacterial or of inorganic agencies). One of the striking features of many shoal-water bottom deposits is the perfection of the preservation of the minute sculpture of foraminiferal shells and alcyonarian spicules. All the facts tend to show that precipitation and not solution is taking place, and it is inconceivable that precipitation and solution could be taking place in the same spot at the same time.

In order to get more information on the subject, Mr. R. B. Dole kindly undertook, at my request, certain chemical examinations of the waters of the Florida reef tract, and of some samples I collected in the Bahamas. The results of studies he made in 1913 were published in an article entitled "Some chemical characteristics of sea-water at Tortugas and around Biscayne Bay, Florida;"[1] and subsequent studies appear in this volume, pages 299–315. As a part of a discussion of the formation of atoll rims, I summarized in the following words the results obtained up to 1914:[2]

"There are two rival hypotheses for the formation of atolls: one of these attributes them to the submarine solution of the interior of a mass of limestone; the other accounts for them by constructional agencies. In order thoroughly to test the solution hypothesis the results of four lines of investigations were brought to bear upon it, and all are accordant. (1) All the bays, sounds, and lagoons within the Florida reef and key region are filling with sediment; (2) Drew's investigations of denitrifying bacteria show that chemical precipitation of calcium carbonate is taking place in the lagoons; (3) the chemical examination by R. B. Dole of samples of sea-water flowing into and out of the Tortugas lagoon, collected twice daily for a lunar period, show that although both carbonate and bicarbonate radicles are in solution uncombined carbon dioxide is not present, and that the water possesses no capacity for further solution of calcium carbonate by virtue of its content of free carbon dioxide; (4) the determinations by Dole of the salinity of the water within the Tortugas lagoon and at the southern end of Biscayne Bay show a higher concentration than that in the open sea-water on the outside, indicating that tidal inflow and outflow are not sufficient completely to mix the water in the lagoons with the water of the surrounding sea and that concentration by evaporation is taking place. As the results of these lines of inquiry are so positive, the formation of lagoons by submarine solution may be definitely eliminated from consideration."

Recently two highly valuable contributions to this subject have emanated from the Geophysical Laboratory of the Carnegie Institution. One is entitled "The rôle of inorganic agencies in the deposition of calcium carbonate," by John Johnston and E. D. Williamson;[3] the other is "The several forms of calcium carbonate," by John Johnston, H. E. Merwin, and E. D. Williamson.[4] Messrs. Johnston and Merwin have kindly lent me copies of their manuscripts, in advance of publication, and have granted me permission to make such citations as were germane to the subjects here under consideration.

Johnston and Williamson say that "the titration methods which have usually been employed for the determination of free CO_2—and to some

[1]Carnegie Inst. Wash. Pub. 182, pp. 69–78, 1914.
[2]Jour. Acad. Sci. Wash., vol. 4, pp. 27–28, Jan. 19, 1914.
[3]Jour. Geol., vol. 24, pp. 729–750, 1916.
[4]Am. Jour. Sci., vol. 41, pp., 473–512, 1916.

extent of combined CO_2—are altogether untrustworthy, since the results depend on the amount of indicator added and upon other factors which have not been adequately controlled." The inference from this statement is that in the writers' opinion the method used by Dole in his work[1] is subject to question. However that may be, geologically speaking the results of Dole and of Johnston and Williamson are identical.

Johnston and Williamson have paid particular attention to the solubility-product constant $[Ca^{++}]$ $[CO_3^{=}]$, the concentration of H_2CO_3, the effect of temperature on H_2CO_3 concentration, and the relation of the solubility-product constant to rise in temperature. Two quotations from this paper follow:

"Now it is possible that calcium carbonate may through the intervention of biologic agencies be precipitated within a medium which is not saturated with it, yet a *permanent* deposit can hardly result unless either (1) the solution in contact with it is saturated with respect to $CaCO_3$, or (2) the precipitated carbonate is protected from the solution by an organic tissue or otherwise, or (3) that the process of deposition is rapid, in water circulating very slowly or not at all, under which conconditions re-solution by diffusion is very slow. The fact therefore that permanent deposits are being formed in many regions of the sea is of itself good evidence that the water in those regions is substantially saturated with respect to $CaCO_3$. Indeed recent experiments of A. G. Mayer[2] show that the sea-water about the coast of Florida is substantially saturated, for shells exposed to it for a year lost no significant weight. Moreover, the investigations of T. W. Vaughan[3] on coral reefs 'show that submarine solution is not effective there [about Florida], as all the bays, sounds, and lagoons are being filled with sediment,' a conclusion which accords 'with the conclusions reached by numerous investigators in the Pacific, which are that the more or less continuous walls inclosing lagoons have been formed by constructional geologic processes and that lagoon channels and atoll lagoons are not due to submarine solution.' We believe therefore that the surface layers of the ocean, except in the Polar regions, and within currents of cold water—in other words, the warmer portions of the ocean—are substantially saturated with $CaCO_3$; but the truth of this belief can not be regarded as established until trustworthy determinations of the several quantities concerned have been made."

They summarize their conclusions as follows:

"In discussions of the mode of deposition of calcium carbonate there is a point which has not received adequate recognition; namely, the concentration of calcium relative to the limiting saturation concentration of calcium carbonate under the particular conditions, or, in other words, the relative degree of saturation of calcium carbonate, and its local variation, throughout the ocean. The neglect of this important point is without doubt due to the erroneous and misleading statements as to the solubility of $CaCO_3$ which have been prevalent. Its solubility under specified conditions can now be calculated with the requisite accuracy; it is affected materially by variations of temperature and of concentration of free CO_2 such as occur in nature. For example, a change in the proportion of CO_2 in the air from

[1]Carnegie Inst. Wash. Pub. 182, p. 71, 1914.

[2]Mayer, A. G., Proc. Nat. Acad., 2, 28, 1916.

[3]Vaughan, T. W, Am. Jour. Sci. 41, 133, 1916; see also his earlier papers, especially in the publications of the Carnegie Institution of Washington.

3.2 to 3.0 parts per 10,000, or an increase of temperature 2° C. would result ultimately in the precipitation of about 2 grams $CaCO_3$ from every cubic meter of a solution saturated with it. Consequently, since there is reason to believe that the surface layers of the sea (except in the Polar regions and within cold currents) are substantially saturated with calcite, precipitation is to be expected wherever the water is being warmed, or is losing CO_2, or both, and this independently of any other agencies. Indeed, these inorganic factors may not safely be left out of account, no matter what be the agency inducing the precipitation; for there appears to be a correlation in that calcareous organisms are more abundant the more nearly satuated with $CaCO_3$ the water is. The view, here emphasized, of the importance of the inorganic factors, does not exclude the other views which have been proposed to account for the deposition of limestones, and is not in conflict with any facts which have been definitely ascertained. Its precise importance could be established only by accurate determination of temperature, salinity and, particularly, of concentration of CO_2—free and total—of the water, carried out systematically over the ocean; such an investigation would have an important bearing on many biological as well as geological questions, and would enable us ultimately to correlate the position and rate of growth of some limestone deposits with cosmogonic factors in a much more satisfactory way than has yet been done."

A very important contribution to the study of the solubility of calcite in sea-water, by Dr. R. C. Wells, appears on pages 316–318 of this volume.

It seems to me that all lines of evidence converge and give the same result, which is that in the shoal waters of the tropics ocean water does not dissolve calcium carbonate, but that the contrary process –precipitation by both inorganic and organic (bacterial) agencies –is taking place. Conditions in the deep sea, and perhaps in the cold waters of high latitudes, are different. For the reasons stated, it is my conclusion that the disappearance of fine material from behind the reefs at Murray Island, Australia, and Cocoanut Point, Andros Island, Bahamas, is due to washing away of the fine material by currents, which are probably caused, in large part at least, by winds and tides.

Such phenomena as those exhibited at Murray Island and at Cocoanut Point are localized. Coral reefs and their associated phenomena do not occur everywhere, but under certain definite ecologic conditions. Bottom deposits formed under other conditions will now be discussed.

FINELY DIVIDED MUD FROM STAGNANT AREAS IN SOUTH BIGHT.

(Sample No. 79, see plate 95.)

The results of a mechanical analysis of a specimen, No. 79, are given in the first table on page 269; the percentage of $MgCO_3$ (hypothetical combination) is stated in the table on page 270. For position of stations indicated by the field numbers see plate 95.

Comparison of the mechanical analysis of sample 79 with the Murray Island and Cocoanut Point samples shows that in the former the percentage of particles of silt and clay size is 57.6, and only from 1.725 to 1.75 (averages) in the latter; while the chemical analyses indicate 2.56 per cent $MgCO_3$ for the former, and from 5.24 to 5.745 (averages) for the latter. The deposits obviously belong to different classes. At station 79, besides the accumulation of fine

Mechanical analyses of Bahaman bottom samples.

[Graphically illustrated on plate 94.]

No., U. S. Bureau of Soils.	Field No. (T.W.V.)	Positions of stations.	2 to 1 mm.	1 to 0.5 mm.	0.5 to 0.25 mm.	0.25 to 0.1 mm.	0.1 to 0.05 mm.	0.05 to 0.005 mm.	0.005 to 0 mm.
26863	71	Great Bahama Bank, between Gun Cay and Northwest Passage; depth about 9 feet.	2.1	16.3	38.2	40.1	1.7	0.3	2.0
26864	79	South Bight; depth 2 or 3 feet........	1.2	5.0	9.1	16.5	10.6	24.5	33.1
26865	83	Shore material; subject to tidal overflow, west side, Andros Island.	9.4	9.6	4.0	8.0	14.4	29.1	26.3
26866	84	Tongue of the Ocean; depth 825 fathoms.	.4	2.2	4.5	11.3	15.5	45.2	20.5
26867	85	Tongue of the Ocean; depth 800 to 820 fathoms.	.1	.5	.6	2.3	7.1	55.3	34.6
26868	87	1 mile west of west end of South Bight; depth about 6 feet.	1.0	1.6	1.7	10.2	25.1	25.8	35.4

Chemical analyses of oolite and bottom samples from Florida and the Bahamas.
(By W. C. Wheeler.)

	Oolite, Boca Grande Key, Florida.	Oolite, Everglades, Miami, Florida.	Oolite, Sharp Point, Andros Island.	Bottom sample[1] (98), east side Marquesas Lagoon, Florida.	Bottom sample[2] (87), 1 mile west of west end of South Bight, Bahamas
Chemical analyses.					
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
SiO_2.......	0.03	[3]8.23	0.07	1.13	0.28
Al_2O_3......	.18	.00	.00	.14	.03
Fe_2O_3......	.22	.21	.13	.21 (total Fe).	.11 (total Fe).
MgO......	Trace.	Trace.	Trace.	1.31	1.25
CaO.......	53.77	51.60	54.57	51.04	52.30
Na_2O......	.90	.11	.14	.....	.....
K_2O.......	Trace.	Trace.	Trace.	.....	.....
H_2O.......	1.21	.17	1.72	2.03 (and organic).	3.16 (and organic).
CO_2.......	42.34	40.11	43.07	41.50	42.45
P_2O_5.......	Trace.	Trace.	Trace.	.....	.....
SO_3.......	.28	Trace.	.14	.....	.....
Cl.........	1.02	.08	.03	.....	.....
Soluble....	.....	.....	.....	[4]2.21	.....
Total..	99.95	100.51	99.87	99.57	99.58
Reduced analyses (hypothetical combinations), H_2O, organic matter, and soluble salts rejected; silica not essential.					
SiO_2.......	0.03	8.19	0.07	1.18	0.29
$(Al, Fe)_2O_3$.	.42	.21	.13	.37	.15
$MgCO_3$....	Trace.	Trace.	Trace.	2.88	2.72
$CaCO_3$.....	99.05	91.60	99.56	95.57	96.84
$Ca_3P_2O_8$....	Trace.	Trace	Trace.	.....	.....
$CaSO_4$.....	.50	Trace.	.24	.....	.....
Total..	100.00	100.00	100.00	100.00	100.00

[1]Sample washed and dried over H_2SO_4.
[2]Sample filtered, washed, and dried over H_2SO_4.
[3]25 per cent soluble SiO_2; the rest of the silica appears to be white sand.
[4]Saline salts not washed out by water in the preparation of the sample.

material by settling in relatively stagnant water, bacterial precipitation is also effective. The country rock is slightly elevated marine oolite and there are some oolite grains derived from it in the deposits. Dr. Cushman has listed the foraminifera and some of the other organisms obtained at this and other stations along South Bight. As the lists show the character of the foraminiferal fauna through the Bight they are all presented on the next page. Station 77 is $5\frac{1}{2}$ sea miles southeast of the northeast end; station 82 about $7\frac{1}{2}$ sea miles east of the west end; the other stations are intermediate in position over a distance of about 10 sea miles, measured in a straight line.

Partial chemical analyses of oolite and bottom samples from Florida and the Bahamas.
(By W. C. Wheeler.)

No.	Locality.	Analyses.				Reduced analysis, hypothetical combinations.			Remarks.
		Insoluble.	CaO.	MgO.	CO_2. calculated.	Insoluble.	$MgCO_3$.	$CaCO_3$.	
		p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	
68	Beach sand from east side of Sands Key, Florida.	1.15	[1]51.77	1.73	42.55	1.11	3.73	95.08	As received.
71	Great Bahama Bank between Gun Cay Light and Northwest Passage, Bahamas.	.13	53.98	.18	42.42	.13	.38	99.49	An oolite.
79	South Bight, Andros Island, Bahamas.	.46	51.75	1.16	42.92	.47	2.56	93.36	Washed and dried in air.
83	Shore material, west side of Andros Island, Bahamas.	.89	43.47	5.82	40.49	.98	13.36	85.66	
84	Tongue of the Ocean, Bahamas.	1.05	51.30	1.85	42.31	1.09	4.02	94.89	Depth 825 fathoms, washed and dried over H_2SO_4.
85	Tongue of the Ocean, Bahamas.	1.34	51.05	1.30	41.52	1.40	2.89	95.71	Depth 800 to 820 fathoms, washed and dried over H_2SO_4.
91	Mud flat, north side Loggerhead Key, east of Sugar Loaf Key, Florida.	1.04	[2]47.86	1.22	38.93	1.18	2.87	95.95	As received.
97	Near obstruction buoy at southwest entrance to Fort Jefferson Channel, Tortugas, Florida.	1.11	51.02	1.77	42.01	1.16	3.86	94.98	Sample washed and dried in air and over H_2SO_4.
100	South of Sand Key, Florida.	1.32	46.76	2.14	39.07	1.48	5.03	93.49	Depth 60 fathoms, as received.
A	Oolite, Queen's Stairway, Nassau, New Providence.	.04	54.47	.36	43.17	.04	.77	99.19	
B	Oolite, north ridge of Seven Hills, New Providence.	.02	55.11	Trace	43.30	.02	Trace	99.98	

[1]Loss up to 150°, 0.44 per cent moisture. [2]Loss up to 150°, 6.77 per cent moisture.

The following are the lists of foraminifera and associated small organisms from South Bight, Andros Island, Bahamas, contributed by Dr. Cushman:

No. 77. South Bight, Andros Island, Bahamas: Material includes fragments of calcium carbonate, worm-tubes, pelecypods and gastropods, ostracods, and numerous foraminifera.

Foraminifera:

Orbiculina adunca, frequent.
Peneroplis pertusus, few.
Quinqueloculina reticulata, few.
Triloculina linneiana, few.
Clavulina angularis, few.
Quinqueloculina agglutinans, few.
Verneuilina affixa, few.
Quinqueloculina sp.

No. 78. South Bight, Andros Island, Bahamas. Material very similar to No. 77.

Foraminifera:

Orbiculina adunca, few.
Quinqueloculina agglutinans, few.
Clavulina angularis, few.
Polystomella striatopunctata, few.

No. 79. South Bight, Andros Island, Bahamas. Material similar to Nos. 77 and 78; more ostracods, fewer mollusca.

Foraminifera:

Orbiculina adunca, common.
Quinqueloculina agglutinans, few.
Verneuilina affixa, few.
Polystomella striatopunctata, few.
Several Quinqueloculina and Triloculina.

No. 80. South Bight, Andros Island, Bahamas. Material similar to No. 78.

Foraminifera:

Orbiculina adunca, frequent.
Quinqueloculina agglutinans, few.
Triloculina linneiana, few.
Verneuilina affixa, few.
Clavulina angularis, few.
Polystomella striatopunctata, few.
Numerous Quinqueloculina and Triloculina.

No. 81*a*. Shore material, South Bight, Andros Island, Bahamas. Many shell fragments. (No. 81*b*, similar.)

Foraminifera:

Orbiculina adunca, frequent, worn.
Quinqueloculina agglutinans, few.
Quinqueloculina reticulata, few.
Triloculina linneiana, few.
Verneuilina affixa, few.

No. 82. South Bight, Andros Island, Bahamas. Material rather poor in organisms except foraminifera.

Foraminifera:

Orbiculina adunca, frequent.
Quinqueloculina agglutinans, few.
Verneuilina affixa, few.
Clavulina angularis, few.
Polystomella striatopunctata, few.

No large testaceous organisms were observed along the Bight, indicating conditions in general unfavorable for life, except bacterial.

SAMPLES FROM OFF THE WEST END OF SOUTH BIGHT.

Sample No. 87 is from 2 miles off the west end of South Bight (for location, see plate 95). I have previously described it and other samples of finely divided mud taken from nearby, and present in slightly modified form the account referred to in the footnote.[1]

A field examination of a bottom sample, No. 177, from 2 miles west of the west end of South Bight, gave the following:

Color: light gray, tinged bluish. Reaction to litmus: strikingly alkaline. Odor: fetid, some H_2S. Cobalt-nitrate test: showed presence of aragonite.[2]

[1] Carnegie Inst. Wash. Year Book 13, pp. 227–228, 1915.

[2] For notes on the aragonite needles in this specimen, see Johnston, Merwin, and Williamson, Amer. Jour. Sci., vol. 41, pp. 508, 509, 1916. They contain 0.7 per cent of $CaSO_4$.

The following is a description of the separates according to size, but the percentage estimates are omitted, as accurate physical analyses of samples are subsequently given:

Description of separates from bottom sample No. 177.

Held on $\frac{1}{20}$ mesh. Tests of *Orbiculina adunca*.
Held on $\frac{1}{40}$ mesh. Quantities of soft, non-indurated as well as indurated oolite grains, the former easily crushed by a touch with the point of a needle. Foraminifera present.
Held on $\frac{1}{80}$ mesh. Many perfect oolite grains; also foraminifera.
Held on $\frac{1}{100}$ mesh. Many soft oolite grains; foraminifera; fragmental particles.
Held on $\frac{1}{200}$ mesh. Small oolite grains and fragmental particles; material predominantly oolitic.
Passed $\frac{1}{200}$ mesh. Quantities of small, globular bodies, minute oolites, and flocculent material.

The separates were compared with the powder of the oolite forming Golding Cay. The mud is clearly oolitic.

The following are accurate physical analyses, made in the Bureau of Soils, Department of Agriculture, of two specimens collected by Mr. Drew in 1912, and of sample No. 177, all of which are oolitic. Specimen No. 87 is from a depth of 7 feet, 2 miles west, and specimen No. 88 from a depth of 8 feet, 3 miles west of the west end of South Bight.

Mechanical analyses of bottom specimens Nos. 87, 88, and 177.

[Graphically illustrated on plate 94.]

No.	2 to 1 mm.	1 to 0.5 mm.	0.5 to 0.25 mm.	0.25 to 0.1 mm.	0.1 to 0.05 mm.	0.05 to 0.005 mm.	0.005 to 0 mm.
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
87	1.0	1.6	1.7	10.2	25.1	25.8	35.4
88	0.6	1.9	4.3	16.1	27.9	19.5	30.3
177	1.6	4.5	5.0	6.3	12.2	31.1	40.1

The calcium carbonate of the specimens comprises both aragonite and calcite.

Dr. Cushman has furnished the following lists of microzoa from samples 87 and 88:

No. 87. A little fragmental calcium carbonate, occasional ostracod valves, and a few foraminifera.

Clavulina angularis.
Orbiculina adunca.
Verneuilina affixa.
Polystomella striatopunctata.
Quinqueloculina, etc.

No. 88. A few shell fragments, fragmental calcium, ostracod valves, and some foraminifera.

Orbiculina adunca.
Peneroplis pertusus.
Peneroplis pertusus var. discoideus.
Verneuilina affixa.
Polystomella striatopunctata.
Quinqueloculina and Triloculina.

The results of a chemical analysis of specimen 87 are given on page 269.

The mechanical analyses give the following percentages of silt and clay for the three samples: No. 87, 61.2 per cent; No. 88, 49.8 per cent; No. 177,

71.1 per cent; average of the three 60.7 per cent, a higher figure than for specimen 79, from South Bight. It was from this locality that Drew collected the samples he used in his study of the bacteria "of the chalky mud flats which are being deposited to the west of Andros Island."[1] Here he found "160,000,000 bacteria per 1 c.c." He says: "The actual number in the mud possibly exceeds this figure, since a large proportion of the bacteria would probably settle with the larger particles after the first dilution." Dr. Kellerman studied a part of specimen No. 177, which I sent him, and essentially confirmed Drew's results.[2] This mud is largely a bacterial precipitate, but, as will presently be shown, other factors which might cause precipitation need to be considered.

Drew did not sound the mud to find out how deep it is. I found the mud at station 177 to be 2 feet thick over hard rock; water 6 feet deep. On the west side of the channel into the west end of South Bight, the water is 2 feet deep, mud 7 feet thick. Except some foraminifera and a few other small organisms, bacteria are almost the only forms of life present. I searched specimen 177 for Coccolithophoridæ and occasionally found one. The almost complete absence of these minute organisms is in contrast to their frequent presence in the samples from Cocoanut Point and Murray Island.

The percentage of $MgCO_3$ is 2.72, a figure about the same as that for specimen 79 (2.56 per cent), but much lower than the one for Cocoanut Point (5.24 per cent). The muds off the west side of Andros are closely similar to those along South Bight.

Some other facts of the physical conditions need consideration. Mr. Dole has determined the salinity of water samples I brought back,[3] and found that at Station 177 to be 3.886 per cent, while two water samples at Cocoanut Point had salinities of 3.64 per cent and 3.66 per cent respectively, showing a distinctly higher concentration on the west than on the east side of Andros Island. Drew obtained the following surface salinities in the Tongue of the Ocean:[4] 6 miles east of Golding Cay, 3.624 per cent; 13 miles east of Golding Cay, 3.658 per cent; figures essentially the same as those reported by Dole.

Data on the surface temperatures of the water on the two sides of the island are deficient. Drew reports surface temperatures of 26.90°, 26.30°, 27.10° C., during May, and I have some additional records, but they are so fragmentary as not to be worth publishing. There are no records for the west side of the island.

The less concentration of salts in solution in the water on the east side of Andros, as compared with that on the west, is to be explained by deep water coming very near shore on the east side, the 50-fathom curve being

[1]Carnegie Inst. Wash. Pub. No. 182, pp. 41–43, 1914.

[2]Carnegie Inst. Wash. Year Book No. 13, pp. 228–229, 1915.

[3]The results of Mr. Dole's investigations of the salinity of the Florida reef tract and of some areas in the Bahamas are given in a subsequent article in this volume, pp. 299–315.

[4]*Op. sup. cit.*, pp. 37, 38.

usually less than 2 miles from shore, and depths ranging from 800 to 1,000 fathoms are only a short distance farther seaward. On the west side there is an enormous flat, which is over 60 sea miles wide along an east and west line, and on it the maximum recorded depth is $3\frac{1}{2}$ fathoms. In a way there is here a great evaporating pan, and a concentration of saline ingredients results. This concentration would cause the precipitation of some $CaCO_3$ even were there no bacteria. It is probable that, especially during the summer months, the temperature of the shoal waters is higher than on the surface of the ocean where the depths are greater. Such an increase in temperature would cause the water to lose CO_2 and produce precipitation of $CaCO_3$. Surface agitation of the water would accelerate the loss of CO_2 and thereby increase the rate of precipitation of $CaCO_3$.

From the foregoing discussion it is obvious that there are at least three cooperating factors tending to produce precipitation of $CaCO_3$, viz: (1) ammonifying bacteria, (2) concentration of salts in solution through evaporation, (3) expulsion of CO_2 by increase in temperature. As these factors have not been evaluated, a satisfactory solution of the complicated problem awaits further research.

SHORE SPECIMEN, NORTH OF WEST END OF SOUTH BIGHT.

(Specimen No. 83; see plate 95 for location.)

This specimen was subject to alternate wetting and drying by the rise and fall of the tide. The mechanical analysis of it is given on page 269 and it is graphically illustrated on plate 94; the percentages of $MgCO_3$[1] and $CaCO_3$ are given on page 270. The percentage of particles of silt and clay size is 55.4; that of $MgCO_3$, 13.36. According to the mechanical analysis, this specimen groups with specimens 79 and 87; but it is higher in $MgCO_3$ than any other of the specimens here considered. There has evidently been secondary concentration of magnesia, perhaps due to alternate wetting and drying by the rise and fall of the tides. The specimen from the northwest end of Murray Island, washed up on the reef, 1,700 feet from shore, has 7.57 per cent of $MgCO_3$, 2.175 per cent higher than the average of the samples taken from the bottom along line I, southeast reef, suggesting that secondary concentration has also taken place in it. Dr. Cushman says regarding this sample (No. 83): "Little of interest in the material. Foraminifera, few, minute, technical species, unlike preceeding (No. 82)."

OOLITIC SAND FROM GREAT BAHAMA BANK.

(Speeimen No. 71; see plate 95.)

The Great Bahama Bank is remarkable in its topographic features. There are thousands of square miles of its surface over which the water ranges in depth from 6 feet as a minimum to about 21 feet as a maximum. I know no other plain so extensive in area and so small in the range of the relief of its surface. Along the line from Gun Cay to Northwest Passage,

[1]Hypothetical combinations.

although the distance is 67 nautical miles, the range in depth is only from 7 to 12 feet. Gun and Cat Cays on the west are composed of oolite, as is Andros Island on the west. This rock extends under sea, and a series of samples taken at intervals across the bank shows its continuity from one side to the other. The last movement of this area with reference to change in sea-level has been by submergence of what was a land area, some parts of which stood at least 198 feet above the sea.[1] During the period of emergence the previously formed oolite was indurated; after its resubmergence waves have broken up the rock and the bottom is now largely covered by an oolitic sand, some grains of which are still embedded in a hard matrix. The paucity of life on this enormous flat is as remarkable as the uniformity of its depth and the continuity of one geologic formation.

The results of a mechanical analysis of sample 71 are given on page 269 and are graphically shown on plate 94. The percentage of particles of silt and clay size is 2.3, very nearly the same as that for Cocoanut Point and Murray Island. The small proportion of material of this size is probably due to currents, both wind-induced and tidal, which set across the bank, as there is open water at the east end of the course indicated, and at its west end there are only a few small cays. The water is also open both to the north and to the south.

The chemical analysis (see page 270) shows only 0.38 per cent of $MgCO_3$, the lowest percentage in any specimen so far considered. The percentage of $CaCO_3$ is 99.49, almost pure calcium carbonate.

It has already been stated that the material is an oolitic sand. The following lists of foraminifera, by Dr. Cushman, show how rare foraminifera are at each of five stations occupied:

No. 71. Great Bahama Bank, 22½ sea miles from Gun Cay, between Gun Cay Light and Northwest Passage.

Foraminifera (few):
- Orbiculina adunca, few.
- Orbiculina compressa, one.
- Quinqueloculina reticulata, one.
- Verneuilina affixa, one.
- Polystomella striatopunctata, one.
- Two or three Quinqueloculina and Triloculina.

No. 72. Great Bahama Bank, 30½ sea miles from Gun Cay.

Foraminifera:
- Orbiculina adunca, few.
- Quinqueloculina reticulata, few.
- Peneroplis pertusus, few;
- Peneroplis pertusus var. discoideus, few.
- Articulina sagra, one.
- Planispirinia exigua, one.
- Clavulina angularis, one.
- Verneuilina affixa, few.
- Few Quinqueloculina and Triculina.

No. 73. Great Bahama Bank, 38½ sea miles from Gun Cay.

Foraminifera:
- Orbiculina adunca, few.
- Peneroplis pertusus var. discoideus, one.
- Quinqueloculina reticulata, few.
- Planispirinia exigua, few.
- Verneuilina affixa, few.

[1] Vaughan, in Carnegie Inst. Wash. Year Book No. 13, p. 230, 1915.

No. 74. Great Bahama Bank, 45½ sea miles from Gun Cay. Material largely sand, much worn, occasional mollusk shells, foraminifera few.

Foraminifera:

Orbiculina adunca, few.	Articulina sagra, one.
Peneroplis pertusus, few.	Verneuilina affixa, few.
Quinqueloculina reticulata, one.	Calvulina angularis, one.
Planispirinia exigua, few.	

No. 75. Great Bahama Bank, 52½ sea miles from Gun Cay. Material similar to No. 74. Foraminifera few and poor.

Foraminifera:

Orbiculina adunca, few.	Planispirinia exigua, few.
Peneroplis pertusus, few.	

It is obvious that this represents a third distinct class of calcium carbonate deposit.

GLOBIGERINA OOZE FROM THE TONGUE OF THE OCEAN.

(Samples 84, depth 825 fathoms, and 85, depth 800 to 820 fathoms, collected by G. H. Drew, see plate 95.)

The mechanical analyses are given on page 269 (graphically illustrated on plate 94); percentage of $MgCO_3$ on page 270. Particles of silt and clay in 84, 65.7 per cent; in 85, 89.9 per cent. Silt in 84, 45.2 per cent; in 85, 55.3 per cent. The large percentage of particles of silt size is striking; it is larger than in any of the other specimens. Percentage of $MgCO_3$, in 84, 4.02; in 85, 2.89. No. 84 has only about 1.5 per cent less $MgCO_3$ than the Cocoanut Point specimens; No. 85 has almost the same as the fine-grained lagoonal deposits (see specimen No. 87). However, the sources of the material in these two samples are different (at least in large part) from that composing No. 87. The following are Dr. Cushman's lists of the organisms, to which Coccolithophoridæ should be added. The material includes a few sponge spicules, occasional alcyonoid spicules, numerous pteropods, some gastropods, few pelecypods, ostracod valves, occasional echinoid spines and fragments of plates, numerous foraminifera of Globigerina ooze species.

No. 84. Tongue of the Ocean (Drew) 825 fathoms.

Foraminifera:

Peneroplis pertusus, few.	Pulvinulina canariensis, few.
Globigerina bulloides, frequent.	Articulina sagra, few.
Globigerina æquilateralis, frequent.	Pullenia obliqueloculata, frequent.
Globigerina dubia, abundant.	Bulimina buchian, few.
Globigerina rubra, frequent.	Cristellaria variabilis, few.
Pulvinulina menardii, frequent.	Truncatulina reticulata, few.
Pulvinulina truncatulinoides, abundant.	Biloculina murrhyna, few.

No. 85. Tongue of the Ocean (Drew) 800 to 820 fathoms.

Foraminifera:

Pulvinulina truncatulinoides, frequent.	Pullenia obliqueloculata, frequent.
Pulvinulina menardii, few.	Pullenia sphæroides, few.
Globigerina rubra, frequent.	Orbulina universa, few.
Globigerina dubia, frequent.	Cymbalopora poeyi, few.
Globigerina æquilateralis, frequent.	Cassidulina subglobosa, few.
Globigerina bulloides, frequent.	Biloculina murrhyna, few.

ELEVATED BAHAMAN OOLITES.

No mechanical analyses of these were attempted, as they would have been impracticable because of induration of the rocks.

Marine-bedded oolite: Sharp Rock Point, Andros Island, Chemical analysis, page 269. $MgCO_3$, trace; $CaCO_3$, 99.56 per cent.

Wind-blown oolite: (*a*) Queen's Stairway, Nassau. Partial chemical analysis. $MgCO_3$, 0.77 per cent; $CaCO_3$, 99.19 per cent. (*b*) North ridge at Seven Hills, New Providence Island. Partial chemical analysis, page 270. $MgCO_3$, trace; $CaCO_3$, 99.98 per cent.

These samples differ from all others, except the oolite sand from Great Bahama Bank, specimen No. 71, in the low percentage of $MgCO_3$, and the high percentage, over 99, of $CaCO_3$. Specimen No. 71 has 0.38 per cent of $MgCO_3$ and 99.49 per cent of $CaCO_3$. Therefore in chemical composition these oolites are more nearly pure calcium carbonate than any other samples at present known from Florida and the Bahamas. This means that although certain leading facts in the formation of oolites have been discovered, conditions absolutely similar to those under which the Bahaman and Floridian oolites formed have not yet been discovered among processes now in operation. The conditions for the formation of such rocks require a more complete suppression of organisms which can contribute $MgCO_3$ to the sediments than those which now prevail in Florida and the Bahamas. The evaluation of the difference between the oolitic muds now forming in Floridian and Bahaman waters and the oolites of greater geologic age exposed in the same areas must be left for future investigation, but that they are not precisely the same is apparent, and the significance of the difference should be investigated.

Here it should also be pointed out that although a certain amount of zonal structure is sometimes found in the oolites of the oolitic muds, there is never so large a number of well-defined concentric shells (or "skins," to use a word suggested by Dr. Merwin) in the mud grains as are usual in the grains of the older rock. That the material has accumulated zonally is obvious, but the precise processes which have determined the zonal arrangement have not been discovered.

A plausible hypothesis is illustrated by the formation of pisolites in hot springs, in which $CaCO_3$ is deposited as more or less spherical bodies from a supersaturated solution. The concretions are kept in motion by ebullition, thereby permitting the formation of successive concentric shells of $CaCO_3$.[1] The principle involved is that the movement of a nucleus or a concretion already initiated within a solution in which $CaCO_3$ is being precipitated furnishes an opportunity for concentric enlargement. Occasional desiccation will emphasize the zonal structure. Of course there is no evidence of hot-spring action in areas underlain by marine oolites, but agencies favoring periodic precipitation combined with the occasional shifting of the position of oolites once started apparently will account for the phenomena.

[1]Hayes, C. W., Science, n. s., vol. 33, p. 550, 1911.

The strong cross-bedding of the Floridian oolites shows that waves and currents did move the oolite grains, and thereby gave them access to more chemically precipitated material.[1]

This brief review of the status of the investigation of the origin of oolites will be closed with the statement that, notwithstanding the appreciable advance toward explaining the formation of these bodies, considerable work remains to be done before we shall adequately understand all the processes involved.

SUMMARY ON BOTTOM DEPOSITS OF THE BAHAMAS.

(1) The foregoing account of the Bahaman bottom deposits shows three prominent classes of shoal-water deposits and one class of deep-water deposits, as follows:

(*a*) Sands such as those forming behind the reef off Cocoanut Point. There is but little silt and clay in this deposit, 1.725 per cent; it is composed mostly of the remains of organisms, entire or comminuted, which live upon or are associated with coral reefs; the percentage of $MgCO_3$ is high, 5.24 per cent; although coral detritus is present in the sand it constitutes less than 50 per cent of the material. This deposit is essentially the same as that forming behind the reef at Murray Island.

(*b*) Lagoon deposits or deposits forming on extensive flats which are protected by land areas on their windward side. These deposits are very fine-grained, the percentage of particles of silt and clay size averaging 60.7 and are largely chemical precipitates. Bacteria appear to be the most important known agents in causing the precipitation, but evaporation and high temperature need further consideration as cooperating factors. Oolite is forming in these muds. $MgCO_3$ constitutes from 2.56 to 2.72 per cent of these deposits, only about 50 per cent as much as in the reef sands. A similar deposit, which had been subjected to alternate wetting and drying by the rise and fall of the tide, has the $MgCO_3$ (hypothetical combination) percentage raised as high as 13.36 per cent (see specimen No. 83).

(*c*) Oolitic sand derived from the breaking up of indurated oolite through wave action. This class of deposit contains but little material of silt and clay size (2.3 per cent) and is mostly composed of coarse and medium sand, 1 to 0.25 mm. in diameter (54.5 per cent). There are few organic remains, and the percentage of $MgCO_3$ is low (0.38 per cent). This oolitic sand differs from the oolitic muds in its larger grain and its lower $MgCO_3$ content. It is identical with the oolite now elevated above sea-level. Comparison of this material with the oolitic muds indicates that, notwithstanding the advance made toward the understanding of the formation of oolite grains, considerable work remains to be done on the processes involved in the formation of the concentric shells of the grains.

These three appear to be the most important classes of shoal-water deposits; but some beach deposits should be placed in a different category.

[1] Vaughan, Carnegie Inst. Wash. Pub. 133, p. 177, 1910.

(*d*) Globigerina ooze, which covers the bottom of the Tongue of the Ocean.

(2) Although the areas covered by the three classes of shoal-water sediments have not been accurately determined, it can be said that the coral reefs off the east side of Andros Island are narrow and interrupted. Figure 4 shows diagrammatically the relations. If all the living corals and the dead coral skeletons forming the modern reefs were put together, I doubt if they would make a continuous ridge 100 feet wide and 12 feet thick the entire length of the east face of the island. The barrier stands from about 0.5 mile to about 2 miles offshore; and the sands form a thin veneer over the oolitic rock which passes below sea-level. Solution wells occur in the oolite beneath sea-level as well as along shore above sea-level. I have already published the estimate "that on Andros Island, Bahamas, the

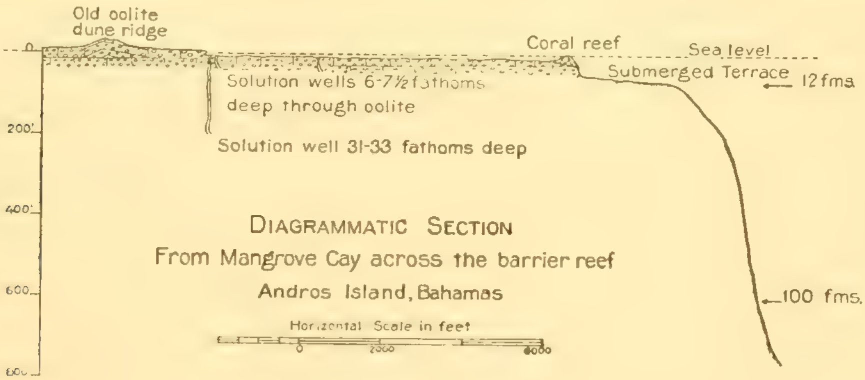


FIG. 4.

ratio of the constructive work of the present reef to that of agencies that previously resulted in the formation of the Pleistocene oolite is approximately as 1 to several thousand, or, as a constructive agent, chemical precipitation has been several thousand times more effective in forming limestone than corals."[1] The classes designated (*b*) and (*c*) are the deposits now forming which are of most importance in shoal water. The growing reef and the sands forming behind it are decidedly subordinate in amount. The area of the deep-water Globigerina ooze has not been ascertained, but it appears safe to assume that it covers the bottom at all depths beyond somewhat less than 800 fathoms.

(3) Examination of the evidence bearing upon the precipitation of $CaCO_3$ in the ocean and the possibility of the solution of $CaCO_3$ leads to the conclusion that in the shoal waters of tropical and subtropical regions precipitation is caused by both organic (bacterial) and inorganic agencies which reduce the CO_2 content of the sea-water; and that no solution of $CaCO_3$ by sea-water is taking place. More detailed studies of the salinity, the temperature, and the CO_2 relations in the ocean are greatly needed.

[1] Jour. Wash. Acad. Sci., vol. 4, pp. 26, 27, Jan. 19, 1914.

(4) The minor chemical constituents of the bottom samples and rocks are as follows: SiO_2, which ranges from 0.07 to 0.29 per cent, an amount so small as mostly to be accounted for by sponge spicules and the few diatoms; $(Al, Fe)_2O_3$ ranges from 0.08 per cent to 0.15 per cent. It is evident that in the Bahamas no appreciable amount of earthy material has been derived from land areas. The small amount of Fe_2O_3, about 0.12 per cent, is sufficient to produce iron stains and red earth when secondarily concentrated. One oolite sample shows a trace of $Ca_3P_2O_8$, but none was found in the bottom samples examined for it. $CaSO_4$ ranges from a trace to 0.24 per cent. The presence of a small amount of $CaSO_4$ seems necessary for the production of aragonite at ordinary temperatures;[1] and as the oolitic muds and oolites are largely aragonite, the importance of $CaSO_4$ is evident.

BOTTOM SAMPLES FROM FLORIDA.

Five bottom samples and two oolite specimens are specially considered. In a previous publication[2] I have discussed in a preliminary way the marine bottom deposits forming in the bays and sounds behind the Florida Keys and Mr. G. C. Matson contributed to the same paper a report on his examination of a set of samples. A smaller number of samples will here be described in more detail than those dealt with in the paper cited.

Specimen No. 68 is a beach sand from the east side of Sands Key, which is near the north end of the line of the Florida keys. (See plate 95.)

Specimen Nos. 91, 97, and 98 are examples of lagoon deposits. No. 91 is from a mud flat north of Loggerhead Key, south of Cudjoe Key and east of Sugarloaf Key; water 3 or 4 feet deep. No. 97 is from near the obstruction buoy, off the northwest entrance to Fort Jefferson channel, Tortugas; depth about 7 fathoms (specimen collected by Dr. A. G. Mayer). No. 98 is from the east side of Marquesas lagoon; water about 1 foot deep. (For position of the stations according to number, see plate 95.)

Specimen No. 100 was taken by Mr. John B. Henderson in water 60 fathoms deep, south of Sand Key light, off Key West. (See plate 95.)

The oolite samples are from Miami and Boca Grande Key.

The following are the results of mechanical analyses (by the U. S. Bureau of Soils) of samples of sea-bottom specimens from Florida:

Mechanical analyses of sea-bottom samples from Florida.

[For graphic illustration, see plate 94.]

No., U. S. Bureau Soils.	No., T. W. V.	Description.	2 to 1 mm.	1 to 0.5 mm.	0.5 to 0.25 mm.	0.25 to 0.1 mm.	0.1 to 0.05 mm.	0.05 to 0.005 mm.	0.005 to 0 mm.
26862	68	Beach sand, Sands Key	47.2	46.1	1.8	1.1	0.3	1.9	2.4
26869	91	Between Loggerhead and Cudjoe Keys	1.7	6.3	4.1	5.9	16.6	27.9	36.6
26870	97	Tortugas lagoon	1.7	2.2	2.3	18.7	37.9	31.0	6.9
26872	100	South of Sand Key, depth 60 fathoms	19.0	22.9	10.1	16.8	7.6	13.0	11.4

[1] Johnston, Merwin, and Williamson, Am. Jour. Sci., vol. 41, p. 509, June 1916.
[2] Carnegie Inst. Wash. Pub. 133, pp. 114–125, 1910.

BEACH SAND FROM SANDS KEY.

The mechanical analysis (sample No. 68) shows that 93.3 per cent of the material is between 2 and 0.5 mm. in diameter, while there is 4.3 per cent of silt and clay size. According to the partial chemical analyses, page 270, there are 3.73 per cent of $MgCO_3$ and 95.08 per cent of $CaCO_3$. There is less $MgCO_3$ than in the material behind Cocoanut Point Reef, but more than in the finely divided muds in South Bight and off the west side of Andros Island.

The following is a list (by Joseph A. Cushman) of the foraminifera from beach sand from east side of Sands Key, Florida, No. 68:

No. 68. Beach sand from east side of Sands Key, Florida.

Orbiculina adunca, abundant.
Orbitolites marginalis, few.
Peneroplis pertusus, few.
Quinqueloculina agglutinans, few.
Triloculina linneiana, few.
Biloculina carinata, few.
Clavulina angularis, few.
Trochammina inflata, one.
Verneuilina affixa, one.
Discorbina vilardeboana, one.
Planorbulina mediterranensis, few.
Quinqueloculina, etc.

The foraminifera in the beach sands on the sea face of keys seem rather consistently to be nearly the same species. Those found on Lisbon Beach, Mangrove Cay, South Bight, Andros Island, Bahamas (identifications by Dr. Cushman), are as follows:

No. 90. Beach sand from Lisbon Beach (east of mouth of Lisbon Creek), South Bight, Mangrove Key, Andros Island, Bahamas. Material fragmentary and water-worn.

Foraminifera:

Orbiculina adunca, frequent.
Quinqueloculina agglutinans, few.
Verneuilina affixa, few.
Triloculina linneiana, one.
Quinqueloculina sp.

The beach sands, naturally, are the coarsest material in the areas here considered. The sizing varies according to local conditions of winds, currents, etc., and as yet has not been adequately studied. The composition also varies from place to place, according to differences in the organisms from which the sands are derived. Efforts are under way to ascertain the sources of the components of a number of beach sands taken from selected localities.

LAGOON SAMPLES.

SAMPLE FROM BETWEEN LOGGERHEAD AND CUDJOE KEYS.

According to the mechanical analysis, 64.5 per cent of specimen No. 91, from between Loggerhead and Cudjoe Keys, is of silt and clay size, nearly the same percentage as in the fine muds in South Bight and west of Andros Island (see plate 94); the percentage of $MgCO_3$ is 2.87, also nearly the same as in the Andros Island specimens. The following is a list of the foraminifera (identification by Dr. Cushman):

No. 91. Mud flat, dredged material, north side of Loggerhead Key, east of Sugar Loaf Key.

Foraminifera:

Polystomella striatopunctata, most frequent species.
Quinqueloculina agglutinans, frequent.
Orbiculina adunca, few.
Triloculina linneiana, few.
Quinqueloculina and Triloculina sp.

This obviously groups with the Bahaman specimens mentioned, Nos. 79, 87, 88, and 177.

Samples from Marquesas Lagoon.

Specimen 98 is from the east side of Marquesas Lagoon (see plate 95). The dimensions of Marquesas Atoll between sea fronts are 4 nautical miles along a line from northeast to southwest and 3 nautical miles from northwest to southeast. The width of the rim ranges up to about 0.625 nautical mile on the northeast side, which is a crescent bowed against the northeast winds. There are entrances to the lagoon in the southeast, southwest, and northwest quadrants.[1] The maximum height of the rim is about 10 feet above low tide. The depths outside the rim range up to about 15 feet within a mile of the shore; within the lagoon the water except along tidal channels is usually less than 3 feet deep, along the channels it is as much as 9 feet in a few places. The bottom of the lagoon is limy mud resting on a floor which lies at a strikingly uniform depth of about 12 feet below low-tide level; one place was found where the depth of mud is 15 feet, below which is rock. The floor underlying the mud is indurated oolite. The lagoon has been filled with mud to an average depth of about 9 feet.

The first cultures Drew made of denitrifying bacteria to ascertain if they would precipitate calcium carbonate were from specimens obtained in Marquesas Lagoon, and Kellerman used specimens from there in his work on the same subject.

I have collected samples at many stations within the lagoon, and have had several mechanical analyses made, but only one chemical analysis. The results of the mechanical analyses of specimens from Marquesas Lagoon (made by U. S. Bureau of Soils) are herewith presented (for graphic representation see plate 94).

Mechanical analyses of bottom samples from Marquesas Lagoon.

No., U. S. Bureau Soils.	No., T. W. V.	Description.	2 to 1 mm.	1 to 0.5 mm.	0.5 to 0.25 mm.	0.25 to 0.1 mm.	0.1 to 0.05 mm.	0.05 to 0.005 mm.	0.005 to 0 mm.
27250	63	SW. quadrant (surface)	1.7	3.1	3.1	17.3	24.8	33.3	16.3
26467	98	SE. quadrant (surface)	4.0	6.4	4.0	19.8	25.6	27.4	12.6
26871	98	.....Do	2.8	6.9	4.5	19.8	24.2	22.0	19.9
27251	106	.....Do	15.9	24.1	10.6	9.1	6.6	17.3	16.4
27252	110	SE. quadrant (9 feet below surface)	1.9	4.3	4.7	18.2	16.5	26.5	28.1
27253	115	SE. quadrant (surface)	.0	17.4	14.0	32.0	13.0	9.7	14.3
27254	117	Outside SE. entrance, water 5 feet deep	.0	17.9	17.5	38.6	7.8	6.5	11.7

The analyses of the surface material indicate an appreciably greater coarseness than that of the muds from South Bight and from off the west side of Andros Island. Only hypothetical explanations can be advanced for this. These are: (*a*) there is greater outwash of fine material; (*b*) bacteria are less abundant. Drew found 800 bacteria per cubic centimeter in a sample sent

[1]For description of the Marquesas, see Vaughan, Carnegie Inst. Wash. Pub. 182, pp. 57–68, 1914; and Vaughan and Shaw, Carnegie Inst. Wash. Year Book No. 14, pp. 232–238, 1916.

to England from the Marquesas; Kellerman found from 3,000 upward per cubic centimeter, but the greatest number per cubic centimeter appears to be off the west side of Andros Island, where, as already stated, it was 160,000,000 per cubic centimeter. As Marquesas Atoll is relatively small and as there are tidal currents across the lagoon, tidal currents aided by wind might remove more fine material than is done on the west side of Andros Island; and the removal of the fine material might reduce the number of bacteria. Other possible factors might operate.

Specimen No. 110 is from 9 feet below the surface on which No. 115 was taken. Specimen No. 110 in sizing is nearly the same as specimen No. 88 from the west side of Andros Island, having 54.6 per cent of particles of silt and clay size, while No. 88 has 49.8 per cent. Specimen 87 has 61.2 per cent of particles of the same size. The deeper material in the core is finer in grain than that on the surface, indicating a change in conditions not now understood.

The chemical analysis of specimen No. 98 (see page 269) shows 2.88 per cent of $MgCO_3$, nearly the same as that for specimen No. 87, from Andros Island. Dr. Cushman furnishes the following notes:

No. 95. Marquesas Lagoon, Florida, small mangrove key east of northwest entrance, inside the lagoon. Worn material with a few pelecypods and fewer gastropods, a very few ostracod valves and few foraminifera.

Foraminifera:
Polystomella striatopunctata, frequent.
Orbiculina adunca, few.
Quinqueloculina.

No. 98. Marquesas Lagoon, Florida, east side. Material includes fragmental calcium carbonate, gastropod and pelecypod shells, numerous ostracod valves, and numerous foraminifera.

Foraminifera:
Orbiculina adunca, few.
Obitolites marginalis, few.
Articulina sagra, few.
Quinqueloculina reticulata, few.
Quinqueloculina agglutinans, few.
Triloculina linneiana, few.
Polystomella crispa, few.
Polystomella striatopunctata, frequent.
Numerous species of Quinqueloculina and Triloculina.

Besides the organisms noted by Dr. Cushman, *Halimeda* is very abundant in places in the lagoon, and the atoll rim is largely composed of more or less broken *Halimeda* joints. There are almost no corals in the lagoon; there is an occasional specimen of *Mæandra areolata*, and, although I seem to have no notes on them, there are almost certainly some colonies of branching species of *Porites*.

Samples from Tortugas Lagoon.

Specimen No. 97 is from Tortugas Lagoon, obstruction buoy, near northwest entrance to Fort Jefferson Channel; depth about 7 fathoms. Many samples have been collected within the Tortugas Lagoon and outside the atoll perimeter, and when properly worked up will add much to the knowledge of the bottom deposits in this area. Only sample No. 97 will be

considered here. The mechanical analysis on page 280 shows 31 per cent of particles of silt, and 6.9 per cent of particles of clay size, 37.9 per cent of the two sizes (see plate 94). The percentage of silt is about that usual in the Tortugas Lagoon deposits; but the percentage of particles of clay size is below the average. The low percentage of the latter size is probably due to outwash by tidal currents. Three samples were collected in the channel off the east side of Garden Key. The clay ranged from 7.7 to 11.5 per cent; silt from 17.9 to 36.3 per cent; silt and clay combined from 25.6 to 47.8 per cent. Where the tidal currents are constricted, much fine material is washed away. The maximum clay in any specimen from the lagoon is 15 per cent; this specimen has 37.9 per cent of silt; the two sizes aggregating 52.9 per cent. The maximum silt in any specimen (one from Bird Key Harbor, depth 6 fathoms) is 56.2 per cent; the clay is 12.6 per cent; the two aggregating 68.8 per cent. In the Tortugas Lagoon deposits there is definitely less material of clay size than in any of the other lagoon deposits here considered; but the percentages of silt and very fine sand seem fairly high.

The percentage of $MgCO_3$ is 3.86 (partial analyses on page 270), distinctly higher than in the other lagoon specimens from Florida and the Bahamas. This higher ratio of $MgCO_3$ is probably to be correlated with the abundance of foraminifera and gorgonian spicules.

Dr. Cushman furnishes the following list:

No. 97. Near the obstruction buoy at southwest entrance to Fort Jefferson Channel, Tortugas, Florida. Material includes fragmental calcium carbonate, fragments and spicules of alcyonoids, fragments of pelecypod and gastropod shells, fragments of worm-tubes, numerous ostracod valves, occasional echinoid spines, and numerous foraminifera.

Orbiculina adunca, few.
Orbiculina compressa, few.
Orbitolites marginalis, few.
Peneroplis pertusus, few.
Quinqueloculina agglutinans, few.
Cornuspira involvens, one.
Virgulina squamosa, few.
Textularia gramen, few.
Textularia agglutinans, few.
Bigenerina nodosaria, few.
Discorbina vilardeboana, few.
Truncatulina rosea, few.
Amphistegina lessoni, few.
Nonionina scapha, few.
Polystomella striatopunctata, few.
Many Quinqueloculina, Triloculina, Biloculina, etc.

It is obvious that according to size the lagoon deposits of Florida represent three grades: (*a*) the finest, is represented by the specimen No. 91 from between Loggerhead and Cudjoe Keys; (*b*) Marquesas Lagoon; (*c*) Tortugas Lagoon. Grade (*a*) is the same as that found off the west side of Andros Island.

SAMPLE FROM OFF KEY WEST.

Specimen No. 100 (see plate 95) (J. B. Henderson, collector) was taken from off Key West, south of Sand Key light, depth 60 fathoms.

As this specimen was taken from the dredge, the mechanical and chemical analyses are not so trustworthy as are those of the other specimens described. (For mechanical analysis see page 280; graphic illustration, plate 94.) The percentage of silt is 13; that of clay, 11.4; the two aggregate 24.4 per

cent, an amount rather less than that in any of the lagoon deposits and strongly contrasting with the Globigerina oozes from the Tongue of the Ocean, specimens 84 and 85. The percentage of $MgCO_3$, however, is higher, being 5.03 per cent. (For chemical analysis see page 270.) This is probably due to the bottom-living foraminifera contributing so largely to the deposit, but Messrs. Clarke and Wheeler have shown that alcyonaria and echinoids are to be counted as other sources of $MgCO_3$. Dr. Cushman furnishes the following list:

No. 100. South of Sand Key, Florida, depth 60 fathoms. Material includes gastropod and pelecypod shells, alcyonoid spicules, some sponge spicules, echinoid plates and spines, a few pteropods, a few ostracod valves, and foraminifera in quantity of Globigerina ooze types as well as bottom foraminifera.

Foraminifera:

Textularia barrettii, frequent.
Textularia trochus, frequent.
Textularia sagittula, few.
Bigenerina nodosaria, few.
Bulimina marginata, few.
Reophax scorpiurus, few.
Saccammina sphærica, few.
Nodosaria vertebralis, few.
Cristellaria calcar, few.
Cristellaria italica, few.
Marginulina costata, few.
Uvigerina tenuistriata, few.
Globigerina conglobata, frequent.
Globigerina sacculifera, frequent.
Globigerina rubra, frequent.
Globigerina dubia, abundant.
Globigerina cretacea, abundant.
Globigerina bulloides, abundant.
Pullenia obliqueloculata, frequent.
Cymbalopora poeyi, few.
Pulvinulina menardii, few.
Pulvinulina elegans, few.
Pulvinulina auricula, few.
Discorbina bertheloti, few.
Nonionina umbilicatula, few.
Polystomella striato punctata, few.
Amphistegina lessoni, few.
Spiroloculina grata, few.
Spiroloculina arenaria, few.

This represents a type of deposit different in a number of characters from the others considered. It is (*a*) relatively coarse grained; (*b*) it has a high $MgCO_3$ content; (*c*) it is composed of both pelagic and bottom-living foraminifera, some of the latter habitat extending into shallow water. There are no *Orbiculina*, *Orbitolites*, or Miliolidæ.

ELEVATED OOLITE.

Only chemical analyses of these rocks are given (see table, page 269). One of the two specimens is from Boca Grande Key, the other, from Miami, Florida. If the SiO_2 is rejected from the analysis of the Miami oolite, the Florida samples are seen to be essentially like those from the Bahamas, and the remarks made on the latter, see pages 277, 278, apply to both.

SUMMARY ON BOTTOM SAMPLES FROM FLORIDA.

(1) Three classes of bottom deposits from Florida have been considered, as follows:

(*a*) Beach sand, which is mostly composed of particles of the size of fine gravel (47.2 per cent) and coarse sand (46.1 per cent), and contains 4.3 per cent of particles of silt and clay size. *Orbiculina adunca* is an abundant foraminifer. The percentage of $MgCO_3$ in the single specimen analyzed is 3.73. As yet a sufficient number of beach sands have not been studied

for a comprehensive discussion of them, but they seem to represent a distinctive class.

(*b*) Lagoon deposits, some of which are essentially like the fine-grained muds forming on the west side of Andros Island. Sizing indicates three grades of these deposits; the finest corresponds to the Andros Island muds; the next grade is represented by the surface deposits in Marquesas lagoon (clay range from 14.3 per cent to 19.9 per cent; silt range from 9.7 per cent to 33.3 per cent); the specimens from Tortugas Lagoon average less clay than those from the Marquesas, but there is overlapping of the grades. The $MgCO_3$ percentage of the Tortugas material (3.86) is somewhat higher than in the other specimens, a fact probably to be accounted for by the abundance of foraminferal shells and alcyonarian spicules.

(*c*) The deposit in 60 fathoms, south of Sand Key light, is intermediate in character between a Globigerina ooze and a shoal-water deposit. It relatively is coarse grained, has a high (5.03 per cent) $MgCO_3$ content, and contains both bottom-living and pelagic foraminifera.

Specimens of sands from behind the reefs have been collected, but will not now be described. The classes of deposits are closely similar to those recognized in the Bahamas.

(2) As compared with other agents, corals are subordinate as extractors of $CaCO_3$ from the sea-water; but a more accurate evaluation of the work of the different agents must wait until the completion of the study of the composition of the samples from the standpoint of the source of its ingredients.

(3) The remarks on the precipitation and possible solution of $CaCO_3$ made on pages 265–268 apply to Florida as well as to the Bahamas.

(4) The SiO_2 content of the Miami oolite (8.19 per cent) is strikingly different from that of the Bahaman oolites and bottom deposit. The silica is clear sand, around which oolite grains have often formed. The oolite on Boca Grande Key, however, contains only 0.03 per cent SiO_2, showing that in Pleistocene time, during the formation of the latter oolite, terrigenous material did not reach so far westward. The beach sand at Sands Key contains 1.15 per cent insoluble matter; the Marquesas Lagoon sample (No. 98) 1.18 per cent SiO_2. Except in Biscayne Bay and the sounds just southward, next the shore, there is almost no sand in the bottom deposits along the east coast of southern Florida and there is none in the other parts of the key and reef area.[1] The amount of $(Al, Fe)_2O_3$ ranges from 0.21 to 0.42 per cent in the Pleistocene oolites; it is 0.37 per cent in the Marquesas sample, No. 98—somewhat more than in similar deposits in the Bahamas. The waters of the Florida reef tract afford a superb example of almost pure limestone forming near a land-mass which is of low relief and across whose surface no large streams flow. $Ca_3P_2O_8$ is absent or is represented only by traces. $CaSO_4$ ranges from traces to 0.50 per cent. The relations of the latter ingredients are as in the Bahamas.

[1]See Carnegie Inst. Wash. Pub. 133, pp. 114–129, 1910.

CONCLUSIONS.

(1) An attempt has been made to outline a method of studying calcium-carbonate bottom deposits, in the hope that progress may be made toward an adequate classification of such sediments. The method includes the consideration of the following subjects, viz: (*a*) mechanical analyses; (*b*) study of the composition of the separates of different sizes and the determination of the percentage composition of each separate according to the origin of its constituents; (*c*) the chemical composition of the different constituents; (*d*) the chemical composition of the entire sample; (*e*) the correlation of the chemical composition of the entire sample with that of its different constituents according to their percentages; (*f*) the conditions under which the deposit is formed, viz: its relations to land areas, the configuration of the bottom, winds, and currents, and the depth, temperature, and salinity of the water in which formed; (*g*) the areal extent, and if possible the volume of the deposit.

(2) Only one class of deposits, the sands forming on the flat behind the reef, is specially considered for Murray Island. The beach sand and gravel, however, represent a deposit of another class.

(3) Three classes of deposits are recognized in the shoal waters of the Bahamas, viz: (*a*) the sands forming behind the reefs are mostly of organic origin and are essentially identical with the sands from Murray Island; (*b*) the fine-grained muds forming in South Bight and on the west side of Andros Island are largely chemical precipitates, the precipitation being due to bacteria, probably acting concomitantly with inorganic agencies, evaporation and expulsion of CO_2 from the sea-water by heat and by surface agitation of the water; (*c*) the oolitic sands of the Great Bahama Bank are due to the breaking up by wave-action of a previously formed oolite. Of the three classes of deposits (*a*) is of least areal extent; the areas covered by (*b*) and (*c*) have not been delimited, but together they cover an area at least 60 times as great as that covered by (*a*). The beach sands probably constitute another class of shoal-water deposit. Globigerina ooze covers the floor of the Tongue of the Ocean.

(4) Deposits similar to classes (*a*) and (*b*) of those from the Bahamas occur in Florida: Class (*b*) (the lagoon deposits) may be subdivided into grades, according to size of grain. The Tortugas Lagoon samples are coarser than those in Marquesas Lagoon, and those from the latter locality are coarser than the Bahaman samples from South Bight and the west side of Andros Island. The beach sands represent a distinctive class of deposits. The relative area occupied by the different classes has not been determined. Corals, however, are subordinate agents. A deposit from an intermediate depth, 60 fathoms, off Sand Key light, presents distinctive characters, as it contains large bottom-living as well as pelagic foraminifera.

(5) Other classes of deposits will be recognized, but at present it appears advisable to concentrate attention on the five or six mentioned in the foregoing paragraphs.

(6) No appreciable terrigenous material (SiO_2 and Al_2O_3) reaches the Bahamas. The percentage of Fe_2O_3, although only about 0.1 per cent, is sufficient to produce iron stains and red earth when secondarily concentrated. Some terrigenous material, mostly quartz sand, is washed into Biscayne Bay, Florida, and into the sounds south of it, but otherwise practically none reaches the key and reef region. The Florida area is therefore a perfect example of limestones forming in shoal water near a land area which is not crossed by large streams. The Fe_2O_3 content of the Florida samples seems somewhat higher, up to about 0.37 per cent, than that of the Bahama samples. A small amount of $CaSO_4$ seems persistently present; this fact is to be correlated with the formation of aragonite, which is so abundant in the chemically precipitated muds and in the Pleistocene oolites; $Ca_3P_2O_8$ is present only as traces.

(7) Shore material, subjected to wetting and drying by the rise and fall of the tides, shows a higher magnesia content than material otherwise similar but not subject to such influences. There has apparently been a secondary concentration of magnesia.

(8) Reconsideration of the evidence bearing upon the precipitation of $CaCO_3$ in tropical and subtropical waters and the possibility of its re-solution by ocean-water leads to the conclusion that precipitation is resulting from both organic and inorganic agencies, and that no appreciable re-solution is taking place in such waters; but there is solution in the depths of the ocean where the temperature is low, and perhaps in the surface waters of high latitudes.

(9) Although much progress has been made toward understanding the formation of oolite grains, the oolitic muds, should they be indurated, would not be precisely the same as the oolitic rocks now elevated above sea-level. The former contain a larger percentage of $MgCO_3$ than the latter, and the zonal structure is not so highly developed. The agencies involved in the formation of the concentric shells of the grains need further study.

(10) Requisites for adequately understanding the CO_2 and $CaCO_3$ relations in sea-water are (*a*) more accurate records of temperature and salinity in the ocean; (*b*) accurate determinations of the CO_2 content of the air above the water; and (*c*) further study of the CO_2 content (free and total) of the water.[1]

[1]It is my desire to give such support as I can command to the suggestions made by Messrs. Johnston, Merwin, and Williamson. The article by Messrs. Dole and Chambers (pp. 299–315) is a valuable contribution to the salinity of the ocean-water at Fowey Rocks, Florida, and in it may be found references to variations in salinity in the Floridian and Bahaman regions. Dr. Wells's study of the solubility of calcite in sea-water in contact with the atmosphere, and its variation with temperature, is based on the same water on which Messrs. Dole and Chambers report, and his results follow theirs, pages 316–318. The large amount of information on the temperature of Florida waters is presented immediately after the paper by Dr. Wells.

FORAMINIFERA FROM MURRAY ISLAND, AUSTRALIA.

By Joseph A. Cushman.

Five lots of material containing foraminifera from Murray Island in the Barrier Reef region of Australia, collected by Dr. A. G. Mayer, were submitted to me by Doctor Vaughan for determination. All were from shallow water and while interesting and rich in the numbers of individuals, the foraminifera belong to comparatively few species.

A comparison with similar conditions in the West Indies is interesting. In the latter region the most common species is *Orbiculina adunca*, a species wanting in the Murray Island material, where the commonest species of any size is *Tinoporus baculatus*. The absence of the very common *Reophax scorpiurus* in the Murray Island material is also worthy of mention. Certain common East Indian and Australasian species such as *Heterostegina depressa*, *Rotalia calcar*, *Calcarina hispida*, *Polystomella craticulata*, and *Quinqueloculina parkeri* are characteristic of the material.

The material of the five lots was from two different lines run on the reef and will be referred to in the list as Nos. 1 to 5 as follows: 1, line I, 200 feet; 2, line I, 600 feet; 3, line I, 1,200 feet; 4, line I, 1,600 feet; 5, line III, 1,700 feet from shore.

Following is a list of the species determined with descriptions of three species which seem to be new.

Textularia agglutinans d'Orbigny. Uncommon at station 5.
Textularia rugosa Reuss. Frequent, stations 1, 3, 4, 5.
Bolivina punctata d'Orbigny. Rare at station 5.
Clavulina angularia d'Orbigny. Rare at station 5.
Discorbis polystomelloides Parker and Jones. A single specimen of this rare species was obtained in the material from station 3. The type specimen was from Australian coral reefs and it has been recorded at but a few stations in the southern Pacific in shallow water.
Discorbis rugosa d'Orbigny. Single specimens from stations 1 and 3.
Cymbalopora pœyi d'Orbigny. Frequent at stations 1, 3, and 5.
Planorbulina larvata Parker and Jones. Rare at station 5.
Truncatulina pygmæa Hantken. Rare at station 2.
Truncatulina culter Parker and Jones. Rare at station 5.
Anomalina grosserugosa Gumbel. Rare at station 3.
Pulvinulina berthelotiana d'Orbigny. Rare at station 1.
Rotalia beccarii (Linne). Few specimens at station 5.
Rotalia calcar d'Orbigny. Abundant in all the material.
Polytrema mineaceum (Linn.). Occurs as incrusting patches on most dead coral. (See plate 97, figs. 1, 1*a*.)
Calcarina hispida H. B. Brady. Frequent at stations 1 and 5.
Calcarina spengleri (Linne). Scattered specimens in all the material.
Tinoporus baculatus (Montfort) Carpenter. Abundant in all the material.
Polystomella macella (Fichtel and Moll). Frequent throughout.
Polystomella craticulata (Fichtel and Moll). Frequent throughout.
Amphistegina lessonii d'Orbigny. Common at all the stations.
Heterostegina depressa d'Orbigny. A few specimens at stations 3 and 5.
Spiroloculina grata Terquem. A few scattered specimens throughout.
Spiroloculina grata Terquem, var. **angulata** Cushman. A few specimens at station 1.

Spiroloculina elegans new species. (Plate 96, figs. 1*a*, 1*b*, 2). Test 1.5 times as long as wide, much compressed, peripheral margin broadly rounded, apertural end somewhat exserted, rounded, sutures distinctly depressed, wall ornamented with a regular pattern of elliptical depressions arranged in rows longitudinally, the depressions of each row alternating regularly with those of the adjacent rows. Length from 0.85 to 1.15 mm. This species reminds one somewhat of some of the species of the Paris Basin described by Terquem, but seems to be distinct from any of those species. It occurred in some numbers at stations 1 and 2. It is close to **S. foveolata.**

Quinqueloculina bicarinata d'Orbigny. A few specimens at station 3.

Quinqueloculina bicornis (Walker and Jacob). Rare at station 2.

Quinqueloculina boueana d'Orbigny. Fairly frequent at stations 1 and 2.

Quinqueloculina parkeri H. B. Brady. Frequent throughout.

Quinqueloculina reticulata d'Orbigny. Scattered specimens throughout.

Triloculina oblonga d'Orbigny. A few specimens at station 2.

Triloculina circularis d'Orbigny. Frequent at station 2.

Triloculina tricarinata d'Orbigny. A few specimens at station 2.

Triloculina bertheliniana H. B. Brady. Specimens of this very rare species occurred at stations 4 and 5.

Triloculina terquemiana H. B. Brady. Specimens were found at stations 2 and 3.

Triloculina linneiana d'Orbigny. Few specimens at stations 1 and 2.

Triloculina striolata new species. (Plate 96, figs. 3*a*, 3*b*, 3*c*). Test 1.5 times as long as wide; peripheral margin distinctly carinate, sutures distinct, slightly depressed; face of the chambers in front view fairly tumid, broad, apertural end but very slightly if at all exserted, the aperture broad, oval, with a rather stout, bifid tooth; surface of the test ornamented with very fine, somewhat broken, obliquely longitudinal striations. Length 1 mm. A few specimens from station 2.

Triloculina subgranulata new species. (Plate 96, figs. 4*a*, 4*b*, 4*c*). Test slightly longer than broad, chambers very tumid, sutures much depressed, peripheral margin broadly rounded, apertures hardly exserted aperture broadly rounded, with a simple or occasionally bifid tooth, surface very finely granular. Length 0.75 to 0.90 mm. Specimens not rare at station 2

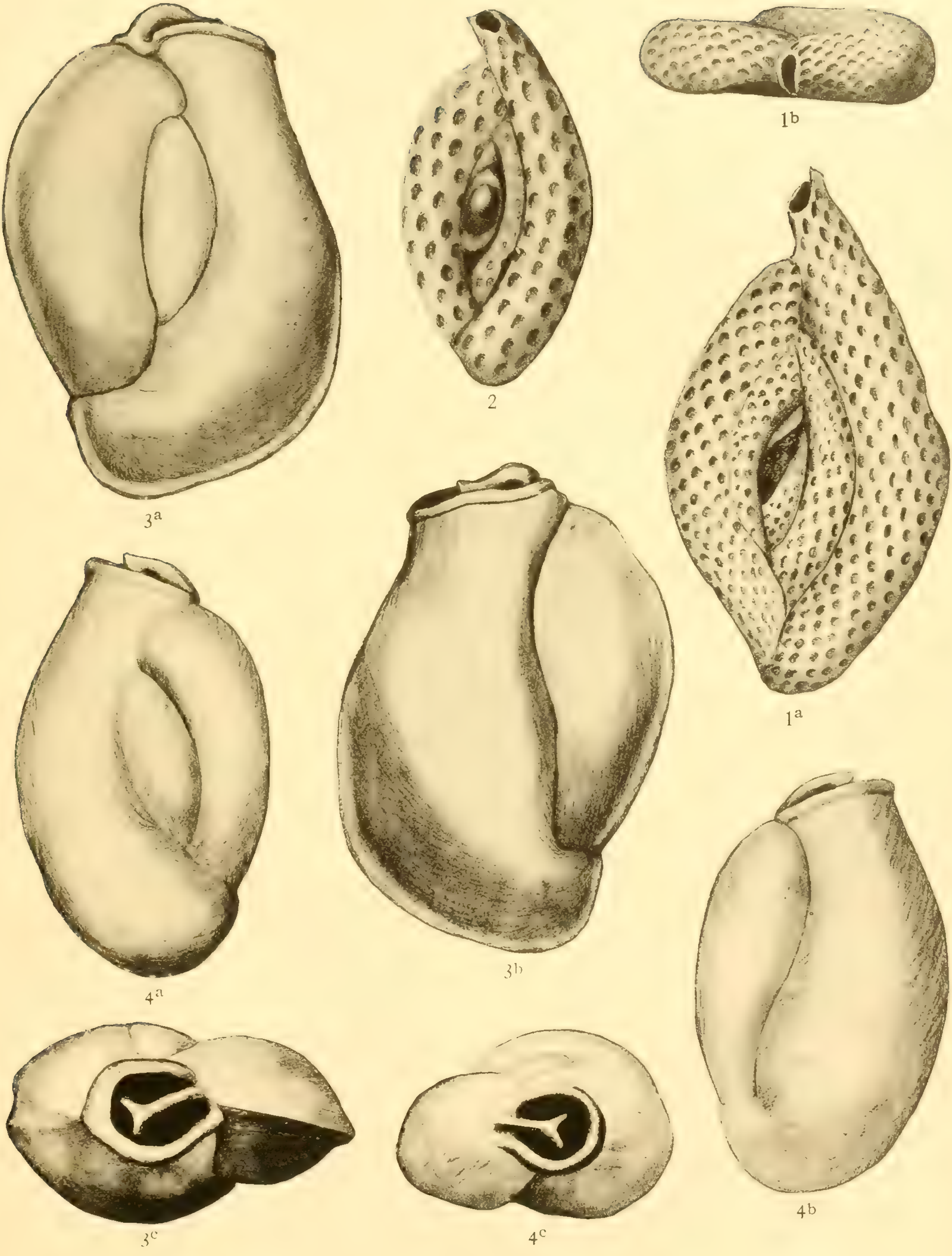
Peneroplis pertusus (Forskål). The typical form of the species was present at stations 1, 2, and 5.

Peneroplis pertusus (Forskål), var. **arietinus** (Batsch). Specimens at station 5.

Peneroplis pertusus (Forskål), var. **planatus** (Fichtel and Moll). Several specimens from station 2.

Orbitolites duplex Carpenter. Few specimens from all the stations, some showing the wing-like secondary growth so frequent in this species. Not as common as the following.

Orbitolites complanata (Lamarck). Frequent at all the stations but the specimens small in size.



MURRAY ISLAND FORAMINIFERA.

FIGS. 1, 1*a*, 1*b*, 2. *Spiroloculina elegans* Cushman, new species.
FIGS. 3, 3*a*, 3*b*, 3*c*. *Triloculina striolata* Cushman, new species.
FIGS. 4, 4*a*, 4*b*, 4*c*. *Triloculina subgranulata* Cushman, new species.

CALCAREOUS ALGÆ FROM MURRAY ISLAND, AUSTRALIA, AND COCOS-KEELING ISLANDS.

By Marshall A. Howe.

Class CHLOROPHYCEÆ.

Family CODIACEÆ.

Halimeda opuntia (L.) Lamour.

Halimeda opuntia (L.) Lamour., Hist. Polyp., p. 308, 1816.
Corallina opuntia L., p. p. Syst. Nat., vol. 1, p. 805, 1758; Ell. and Soland., Nat. Hist. Zooph., p. 110, 1786.

"800 feet from shore, line I, southeast reef."

Class RHODOPHYCEÆ.

Family CORALLINACEÆ.

Goniolithon orthoblastum (Heydrich) M. A. Howe.

Plate 97, figure 2; plate 98, figures 1, 2.

Lithothamnion orthoblastum Heyd., Ber. deutsch. bot. Ges., Bd. 19, p. 403, 1901.

Thallus forming closely adherent crusts 0.5 to 3 mm. (mostly 0.75 to 1.5 mm.) thick or becoming 5 to 8 mm. thick through superposition, somewhat plane, or more commonly irregular through following the inequalities of the substratum, or finally showing here and there proper excrescences, these subhemispheric, obtusely subconic, stalactiform, or difform, 2 to 10 mm. broad and 3 to 20 mm. high, the surface dull, rather smooth, or in fertile parts becoming minutely foveolate-verruculose; primary hypothallium large-celled and usually conspicuous, mostly 200 to 600μ thick, succeeded by alternating, usually sharply defined zones of perithallia and secondary hypothallia, the perithallic zones often abortive and indicated only by a layer of intracellular papillæ resulting from the fusion of small potentially perithallic cells to form a layer of the much larger cells of a secondary hypothallium; cells of primary hypothallium 30 to 85μ by 20 to 44μ, in distinct or often rather indistinct "coaxial" layers, cells of secondary hypothallia commonly a little smaller and less regularly arranged; perithallic cells mostly 8 to 20μ in longest diameter, abruptly smaller than hypothallic cells, subglobose, ovoid, or difform, often irregularly curved, lobed, or constricted, varying from twice as high as broad to twice as broad as high; "heterocysts" or adventive hypothallic cells of frequent occurrence in perithallic layers, scattered or irregularly grouped; conceptacles small, slightly elevated, subhemispheric, 220 to 320μ in diameter, not becoming imbedded, the usually depressed pore about 25μ broad.

From the "Lithothamnium ridge, southeast reef, 1,720 to 1,785 feet from shore."

In the determination of this remarkable plant, the writer has been able to compare with it original specimens of *Lithothamnium orthoblastum* from the Heydrich herbarium, coming from the Tami Islands, German New Guinea, which is in the same floral region. The correspondence in habit and more especially in structure is so close as to leave no possible doubt as to the specific identity of the two plants. The crusts of Dr. Mayer's specimens are less superposed and consequently somewhat thinner and the proper elevations or excrescences are less numerous and less well developed, being only 2 to 10 mm. high and 2 to 5 mm. thick.

The description as given above is drawn to cover both the original material and Dr. Mayer's specimens, which seem to represent the second recorded collection of this interesting species. Many of the elevations of

the thallus of *L. orthoblastum* are obviously due to its close adherence to worm-tubes and other salient irregularities of the substratum, but a cross-section or fracture of these elevations indicates that they are also often proper excrescences.

Among the remarkable characteristics of *L. orthoblastum* are the very large cells of the hypothallium, which give the lower part of the thallus in a vertical fracture an alveolate-vesicular appearance under a hand lens. Another striking and apparently constant peculiarity is the presence of numerous layers of hypothallic cells with intracellular papillæ from their basal faces, these cells and papillæ evidently resulting from the fusion of the much smaller cells of an abortive or suppressed perithallic layer. This character was not mentioned by Heydrich in his description of the species and, so far as the present writer knows, nothing quite comparable has hitherto been recorded for any species of the Lithothamnieæ, though Mme. Lemoine[1] has mentioned the frequent fusion of two cells to form one in *Lithothamnium calcareum.*

The generic position of this plant is open to question, but the present writer believes that it has more in common with the species currently referred to *Goniolithon* than with those that are now referred to *Lithothamnium*. Heydrich believed that he saw rudimentary or immature sterile sori of the sort that characterize the genus *Lithothamnium* as now interpreted. He says in regard to this:

"Der sterile Sorus besteht somit nur aus der flachen, 250 μ im Durchmesser fassenden Decke, welche 5–10 μ über die Cuticula hervorragt und von fast 100 Pori durchbrochen wird. Die einzelnen Pori sind deutlich und leicht in der Flächenansicht zu unterscheiden, können aber in einem entkalkten Längsschnitt kaum nachgewiesen werden. Eine eigentliche Höhle entsteht mithin nicht, wohl aber wird durch die abfallende Decke eine kleine Vertiefung zurückgelassen."

The present writer also has observed, both in the New Guinea and the Murray Island specimens, minute pores arranged somewhat as in a *Lithothamnium* sorus and sometimes on a slight elevation, but the pores are smaller than in ordinary species of *Lithothamnium* and sections show only immersed flask-shaped cells about 40μ high and 20μ broad, looking a little like the sporangia of an *Archæolithothamnium*, but probably representing some parasite or endophyte or cells that have been occupied by some such foreign organism. Occasionally a second cell is observable at the base of such cells, appearing to penetrate the tissues of the host after the usual fashion of endophytes or parasites. The flask-like cells have snout-like prolongations that are carried a little beyond the general surface, and the exserted snout often shows a flaring mouth through which the contents of the cell are apparently discharged. These groups of immersed flask-shaped cells certainly occur on the same individuals that bear the ordinary conceptacles referred to in the above diagnosis—sometimes within 0.5 mm. of the ostiole of such a conceptacle.

[1]Ann. Inst. Océanog., t. 2, fasc. 2, p. 64, 1911.

They are usually empty, so far as observed, but in the few that show protoplasts, no regular divisions have been noted.

The conceptacles are very numerous in the original materials from New Guinea described by Heydrich, and are moderately abundant in certain parts of the specimens from Murray Island. In the many microtome sections that the writer has made from decalcified material, both of the New Guinea and the Murray Island specimens, the conceptacles have been found either empty or with disorganized or fragmentary inclusions that have given no certain clue as to the nature of the conceptacles. Heydrich assumes that they are cystocarpic, but fails to give any description of their contents. None of these cavities shows any traces of the tuft of central paraphyses that have been supposed to be characteristic of at least the tetrasporangial conceptacles of the genus *Lithophyllum*, and, on the other hand, none of them shows the elevated cylindric caducous ostiole that characterizes many of the species currently referred to *Goniolithon*. But the West Indian *Goniolithon boergesenii* Foslie has no such elevated ostioles—in fact, it has conceptacles of very much the same external appearance as those of *G. orthoblastum*, though smaller. The zonated appearance of a cross-section of the thallus, due chiefly to interpolated secondary hypothallia, regularly or irregularly developed, is more characteristic of the genus *Lithothamnium* than of the genus *Goniolithon*, but the general arrangement of the cells, their firm walls, and the presence of scattered "heterocysts" in the perithallic layers induce the writer to place this curious plant in *Goniolithon* rather than in any other of the now recognized genera.

In its highly developed and large-celled hypothallium the later-described *Goniolithon megalocystum* Foslie,[1] from the Karkaralong group of islands of the Dutch East Indies, is somewhat suggestive of *G. orthoblastum*. The writer knows this from description, photographs, figures, and a minute fragment of the type; its hypothallic cells would appear to be smaller (25 to 40 μ by 10 to 18 μ), and its conceptacles (sporangial) much larger (1.5 to 2.0 mm.); it has no frequently alternating zones of perithallia and secondary hypothallia, and it shows no layers of hypothallic cells with intracellular papillæ from their basal walls, which constitute such a striking and peculiar feature of *G. orthoblastum*.

The genus *Goniolithon*, as first[2] proposed by Foslie, differed from the *Goniolithon* as emended by him two years later[3] in the diagnostic characterization, in the specified type, and in general species content. The designated type of 1898, *Goniolithon papillosum* (Zanardini) Foslie, was in 1900 placed by Foslie in *Lithophyllum* and the name *Goniolithon* was then transferred to another list of species with type unspecified but with *G. brassica-florida* (Harvey) Foslie standing first. If this transfer of *G. papillosum* to *Lithophyllum*

[1]Siboga-Exped. Monog. 61, p. 48, figure 20 + plate 9; figures 8, 9, 1904.
[2]K. norske Vidensk. Selsk. Skr., 1898, No. 2, p. 5, 1898; 1898, No. 3, p. 8, 1898.
[3]K. norske Vidensk. Selsk. Skr., 1900, No. 5, p. 15, 1900.

is justifiable, the first *Goniolithon* Foslie becomes, under the "American Code" of nomenclature, a synonym of *Lithophyllum*, while the second *Goniolithon*, being a homonym of the first, is invalid, though under the "Vienna Rules" of nomenclature such a change in the application of the generic name might be tolerated. However, the definition of genera among the Lithothamnieæ is at present on such an uncertain basis and so many questions of generic priority and typification in this group remain to be solved that the writer is not now disposed to disturb current usage by trying to suppress the name *Goniolithon*. The species recognized under this generic name by Foslie in 1900 and afterwards, and later by De-Toni[1] and by Svedlius,[2] seem to form a very natural group, which may well deserve generic recognition. Mme. Lemoine, in her recent[3] attempt to emphasize the importance of vegetative characters in defining genera in this family, has reduced *Goniolithon*, even in its second application, to a synonym of *Lithophyllum*. But, even in their vegetative anatomical characters, the species of *Goniolithon* in its secondary sense, so far as they are known to the writer, offer certain points of difference from the typical species of *Lithophyllum* in its current application. The cells, especially the perithallic, are less distinctly and regularly stratified than those of species of *Lithophyllum*, this difference being due in part but not wholly to the usual occurrence in the perithallia of larger, firmer-walled, for the most part irregularly disposed cells known as "heterocysts." And the cell-walls, particularly those of the hypothallic cells, appear to be firmer and more rigid than those of species of *Lithophyllum*; at least, when decalcified and stained with hematoxylin, they seem to have a peculiar texture and color that, once grasped, is easier to recognize than to describe. However, as has been emphasized by Svedelius (*loc. cit.*, p. 275), it was upon the characters of the tetrasporic and cystocarpic conceptacles that Foslie based his second *Goniolithon*, and, as is now generally recognized by phycologists, it is on such characters that genera are most naturally and firmly grounded. Just how constantly the species currently grouped under *Goniolithon* may differ from those currently grouped under *Lithophyllum* in the character of their conceptacles is to be determined by future investigations.

Goniolithon fosliei (Heydrich) Foslie.

Goniolithon fosliei (Heyd.) Fosl., in Gardiner, Faun. and Geog. Maldive and Laccadive Arch., vol. 1, p. 470, plate 25, fig. 3, 1903; Siboga-Exped. Monog. 61, p. 46, fig. 19 + plate 9, fig. 1–5, 1904.
Lithothamnion fosliei Heyd., Ber. deutsch. bot. Ges., Bd. 15, p. 58, fig. 1 + plate 3, figs. 9–11, 1897.
Lithophyllum fosliei Heyd., Ber. deutsch. bot. Ges., Bd. 15, p. 410, 1897; Lemoine, Ann. Inst. Océanog., t. 2, fasc. 2, p. 142, fig. 71, 1911.

Forming a closely adherent crust on old corals, "1,400 feet from shore, line I, southeast reef." The crusts are 0.5 to 1 mm. thick; the hypothallium is well developed and "coaxial," its cells mostly 24 to 38 μ by 12 to 22 μ; the cells of the perithallium exceedingly variable in size, 9 to 25 μ in maximum diameter, mostly subquadrate in section, but often twice as broad as high or *vice versa*; heterocysts numerous and occasionally in vertical rows as described for *G. fosliei* by Heydrich and by Foslie; the few conceptacles 0.6 to 1 mm. broad, measured from above.

[1] Syll. Alg., vol. 4, pp. 1797–1804, 1905.
[2] In Engler und Prantl, Nat. Pflanzenfam., Theil 1, Abth. 2, Nachträge, pp. 269, 275, 1911.
[3] Ann. Inst. Océanog., t. 2, fasc. 2, p. 64, 1911.

In determining this species the writer had access to several specimens from the Heydrich herbarium and from the original locality (El Tor, Red Sea) and collector (Kaiser), as well as to the published descriptions and figures. The crusts are thinner than most of the crusts of this authentic material, but no thinner than some of them.

Goniolithon myriocarpum (Foslie) Foslie.

Goniolithon myriocarpum (Fosl.) Fosl., Siboga-Exped. Monog. 61, p. 45, plate 9, figs. 6, 7, 1904 [as *G. myriocarpon*].
Lithothamnion myriocarpum Fosl., K. norske Vidensk. Selsk. Skr., 1897, No. 1, p. 19, 1897.

"1,400 feet from shore, line I, southeast reef"; also "1,000 feet from shore, line I, southeast reef."

Forming closely adherent crusts 200 to 700μ thick on old corals. Hypothallic cells mostly 18 to 26μ by 8 to 13μ, for the most part not very obviously stratified. Perithallic cells 5 to 9μ long, heterocysts sometimes infrequent, 18 to 25μ long. Conceptacles 300 to 400μ in diameter. In structure it is rather suggestive of the West Indian *G. accretum* Foslie and Howe,[1] though the hypothallium is commonly better developed.

This plant is referred here with some doubt, but it seems to have enough in common with Foslie's description and figures of *G. myriocarpum* to justify this provisional disposition of it. It would appear to differ, if at all, in the somewhat thicker crusts and smaller conceptacles. All of the conceptacles sectioned have been found essentially empty, so it can hardly be determined whether they are cystocarpic or tetrasporic, though indications that they are not antheridial have been noted. The type of *G. myriocarpum* came from the Red Sea, but the species has since been reported also from the Celebes, New Guinea, etc.

Goniolithon frutescens Foslie.

Goniolithon frutescens Fosl., K. norske Vidensk. Selsk. Skr., 1900, No. 1, p. 9, 1900; Siboga-Exped. Monog 61, p. 53, plate 10, figs. 7–13, 1904.

"400 feet from shore, line I, southeast reef." In typical form. The type of the species was from Funafuti.

Lithophyllum oncodes (Heydrich) Heydrich.

Lithophyllum oncodes (Heyd.) Heyd., Ber. deutsch. bot. Ges., Bd. 15, p. 410, 1897.
Lithothamnion onkodes Heyd., Bibl. Bot., Bd. 7, Heft. 41, p. 6, plate 1, figs. 11*a* and *b*, 1897.
Goniolithon? onkodes Fosl., K. norske Vidensk. Selsk. Skr., 1898, No. 3, p. 8, 1898.
Porolithon oncodes Fosl., K. norske Vidensk. Selsk. Skr., 1909, No. 2, p. 57, 1909; Lemoine, Ann. Inst. Océanog., t. 2, fasc. 2, p. 160, 1911.

On fragment of coral, "1,400 feet from shore, line I, southeast reef"; with *Goniolithon myriocarpum* (Foslie) Foslie, on fragments of coral, "400 feet from shore, line I, southeast reef"; also, on old corals, "800 feet from shore, line I, southeast reef." The type of *L. oncodes* came from the Tami Islands, German New Guinea.

Lithophyllum moluccense (Foslie) Foslie.

Lithophyllum moluccense (Fosl.) Fosl., K. norske Vidensk. Selsk. Skr., 1900, No. 6, p. 12, 1901; Siboga-Exped. Monog. 61, p. 67, figs. 25, 26, plate 12, figs. 2–13, 1904. Lemoine, Ann. Inst. Océanog., t. 2, fasc. 2, p. 135, figs. 65–68, 1911.
Lithothamnion moluccense Fosl., K. norske Vidensk. Selsk. Skr., 1897, No. 1, p. 12, 1897.
Lithothamnion tamiense Heyd., Bibl. Bot., Bd. 7, Heft. 41, p. 1, plate 1, figs. 4–7, 1897.
Lithothamnion pygmæum Heyd., Bibl. Bot., Bd. 7, Heft. 41, p. 3, plate 1, figs. 8–10, 1897.
Lithophyllum pygmæum Heyd., Ber. deutsch. bot. Ges., Bd. 15, p. 412, 1897.
Goniolithon moluccense Fosl., K. norske Vidensk. Selsk. Skr., 1898, No. 3, p. 8, 1898.
Goniolithon tamiense Fosl., K. norske Vidensk. Selsk. Skr., 1898, No. 3, p. 8, 1898.
Goniolithon pygmæum Fosl., K. norske Vidensk. Selsk. Skr., 1898, No. 3, p. 8, 1898.

"1,600 feet from shore, line I, southeast reef flat, water about 10 inches deep at lowest tide."

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[1]Bull. N. Y. Bot. Garden, vol. 4, p. 131, plate 85, figure 2; plate 91, 1906.

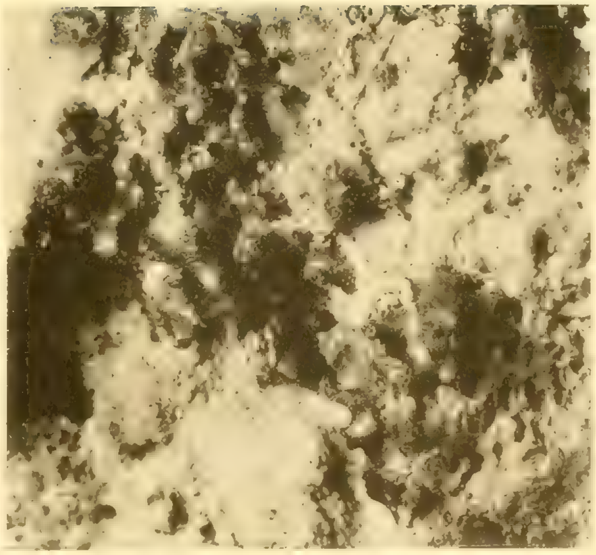
For the determination of this species the writer has had access to specimens of *Lithophyllum moluccense* Foslie from the Dutch East Indies named by Foslie and also to authentic material of *Lithothamnion tamiense* Heydrich and *L. pygmæum* Heydrich from the Tami Islands, German New Guinea.

CORALLINACEÆ FROM COCOS-KEELING ISLANDS.

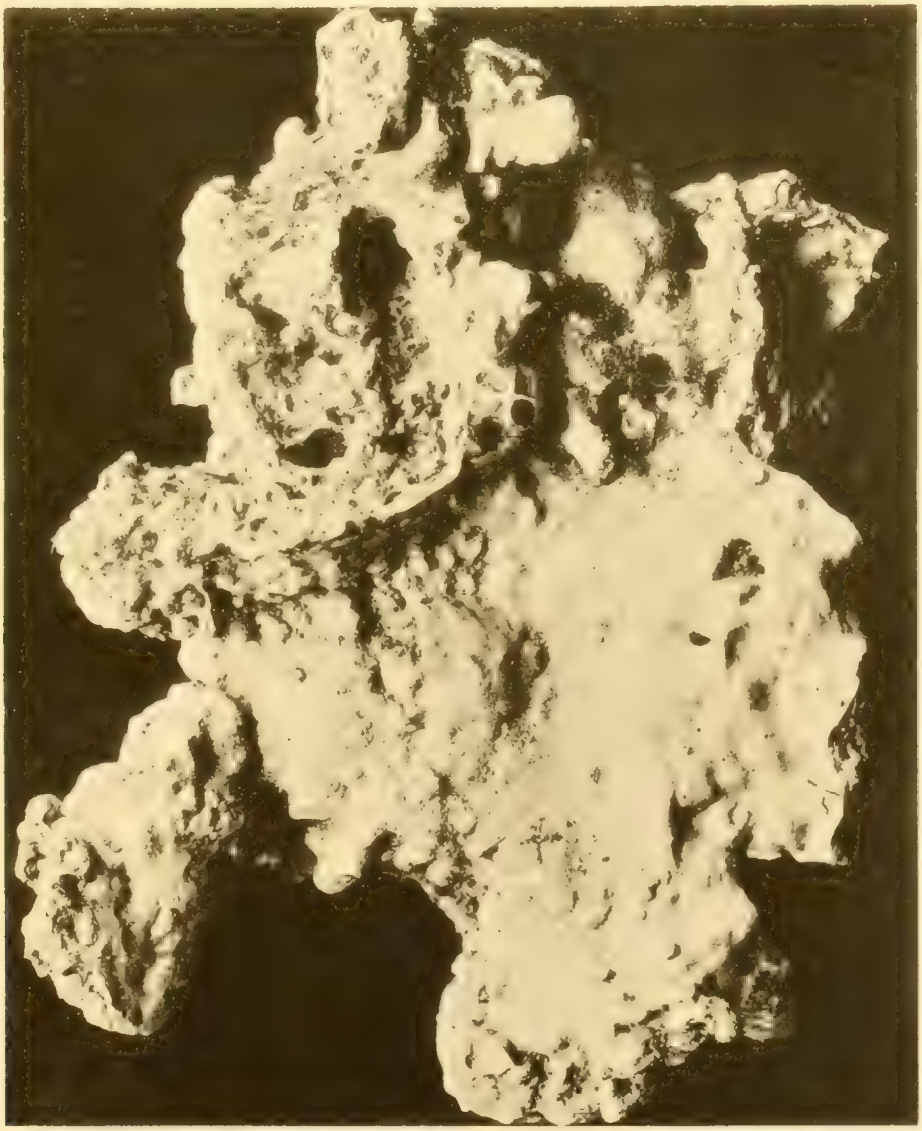
Goniolithon frutescens Fosl. Nos. 120 and 121 and specimens designated as A, B, C, and Y.
Lithophyllum okamurai Fosl. The specimen designated as D.
Lithophyllum kaiseri Heyd. The specimens designated as *x* and *z*.

Collected by F. Wood Jones.

1



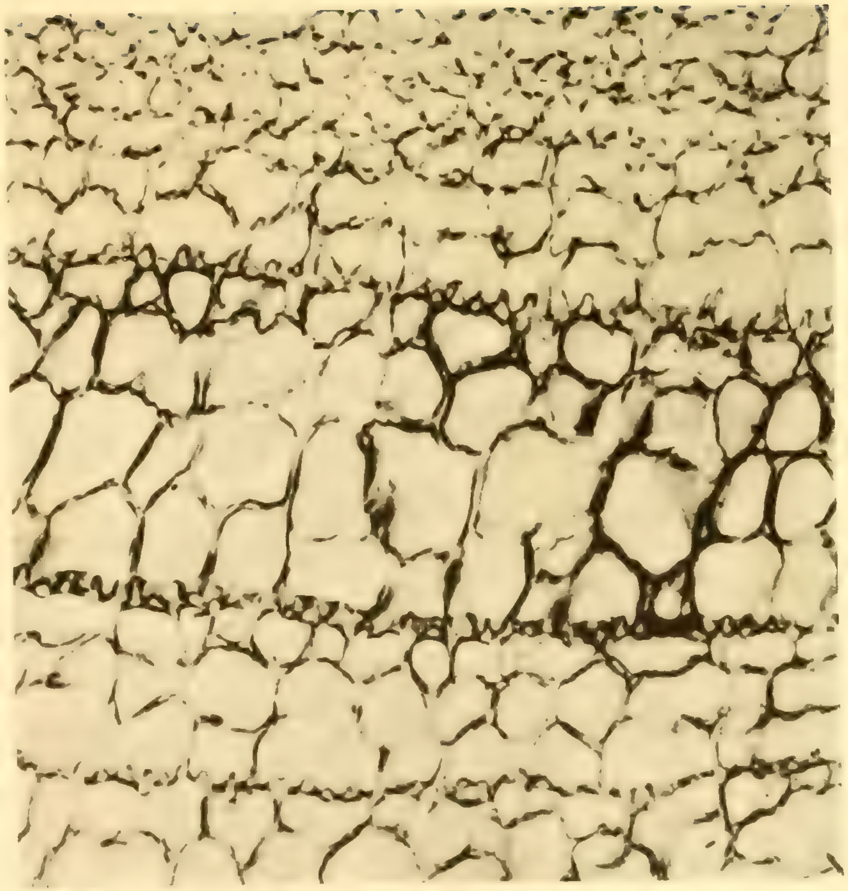
1a



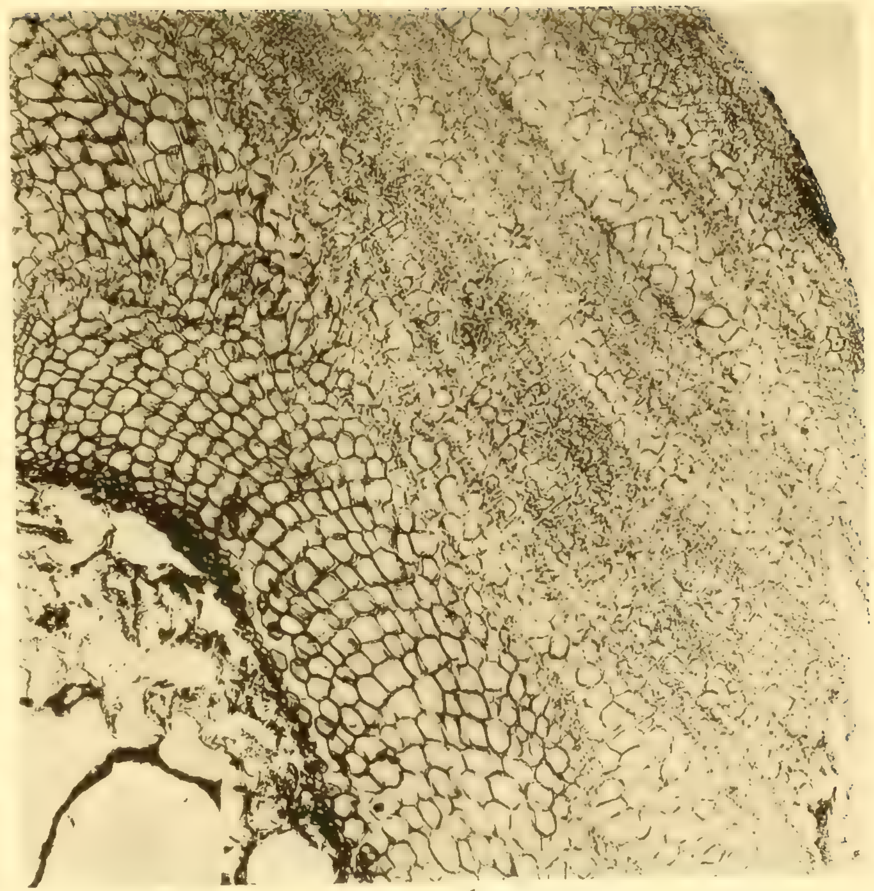
2

FIGS. 1, 1*a*. *Polytrema mineaceum* (Linn.), a common incrusting species of foraminifera from Murray Island; fig. 1, natural size; fig. 1*a*, ×4. (See Dr. Cushman's article, pages 289, 290).

FIG. 2. *Goniolithon orthoblastum* (Heydrich, M. A. Howe). Photograph of specimen from Murray Island, natural size. The original specimens from New Guinea have more numerous, higher, and more stalactiform elevations. Penciled crosses indicate places from which fragments were taken for sectioning.



2



1

Goniolithon orthoblastum (Heyd.) M. A. Howe.

1. Photograph of a portion of a decalcified vertical section, showing basal hypothallium, alternation of perithallia, and secondary hypothallia, etc., enlarged 88 diameters.
2. Photograph of a portion of a decalcified vertical section, showing three abortive perithallic zones, each represented by a layer of fused cells with intracellular basal papillæ, enlarged 408 diameters.

FLORIDA KEYS AND REEFS, FROM KEY BISCAYNE TO RAGGED KEYS

Part of United States Coast and Geodetic Survey Chart No. 166. Scale $\frac{1}{80000}$

DIATOMS FROM MURRAY ISLAND, AUSTRALIA.

By Albert Mann.

Of 7 samples submitted, the 5 examined by Dr. Cushman were destitute of diatoms. Of the 2 fresh samples, that from line I, 200 feet, contained an occasional diatom, but may be said to be practically without these organisms. The sample from line I, 600 feet, was also exceedingly poor in the number of diatoms, but contained a relatively large number of species, as follows:

Navicula lyra Ehr. var. elliptica V. H.
N. suborbicularis Lag.
M. æstiva Donk.
N. aspera (Ehr.) Kg.
N. sp.? (perhaps wide var. N. arenaria).
Amphiprora maxima Greg.
Amphora ovalis Kg.
A. ventricosa Greg.
A. pellucida Greg.
Coscinodiscus elegans Grev.
Cocconeis scutellum Ehr.
Pleurosigma strigosum W. S. var.
Melosira sulcata (Ehr.) Kg.
Cymbella scotica W. S.
Climacosphenia moniligera Ehr.

Few if any of these forms were deficient in silica, unless it was the *Pleurosigma;* but it is significant that this collection has a comparatively large number of species of marine diatoms and yet an extreme poverty in the quantity of these organisms. This indicates to me that the locality in which they were collected was abundantly supplied with individuals of various species, fitted to multiply and inhabit these waters, and probably more or less introduced from other localities, but that for some reason none of these increased to any great extent. Therefore, with an exceedingly varied flora of the diatoms we have an unusually scanty quantity of these organisms. Had there been only one or two species found, this state of things might be interpreted in a different way, but the great diversity of species and the great poverty in numbers leave no explanation except that the waters of this locality were unfitted for diatom development.

RICHARD BRYANT DOLE.

May 8, 1880—January 21, 1917.

After this volume was in page proof and Mr. Dole had corrected the proof of the article by him and Mr. Chambers, his scientific colleagues and other friends were shocked and grieved by his death on January 21, at the end of a brief illness. Although he was only 36 years old at the time of his death, he had made a notable scientific record. He was active in many kinds of chemical work, but devoted his attention especially to a study of the composition and quality of the surface and ground waters of the United States. The prosecution of these investigations led him to consider problems of the chemical denudation of the continents and the transfer of material by running waters to the ocean. He recognized the value of these results in the study of the degradation of the continents and the history of the ocean, and his is the most monumental contribution to the subject as yet made by any man, but he had not completed the great task he had set himself. We mourn the loss of a genial, loyal friend, and an able scientific investigator whose place will long remain unfilled.

THOMAS WAYLAND VAUGHAN.

SALINITY OF OCEAN-WATER AT FOWEY ROCKS, FLORIDA.

By Richard B. Dole and Alfred A. Chambers,
Chemists, U. S. Geological Survey.

Plate 99; text-figures 6, 7.

The following study of the salinity of ocean water off the coast of Florida was made at the request of Dr. T. W. Vaughan, of the U. S. Geological Survey, in connection with his investigations of the deposition of limestone along the Atlantic Coastal Plain, and the analytical results serve to amplify the information gained by the world-wide study of the concentration of ocean water that has been fostered by the Conseil permanent international de la Mer.

Fowey Rocks, on the eastern edge of the coral reefs bordering Biscayne Bay (see plate 99), is the site of a lighthouse known as Fowey Rocks Light. The light is 15 miles S. 25° E. of Miami, 6½ miles S. 35° E. of Cape Florida on Key Biscayne, about 4 miles east of the main series of reefs and keys bordering Biscayne Bay, and about 12 miles east of the mainland. A mile or two east of the light the floor of the ocean is 600 to 1,200 feet below sea-level under the western margin of the Gulf Stream. According to observations of the U. S. Coast and Geodetic Survey the average current 8 miles east of Fowey Rocks is 2.6 knots and 11.5 miles east is 3.6 knots an hour.[1] Consequently the salinity of the water in the vicinity of Fowey Rocks might be expected to represent with fair accuracy that of the Gulf Stream shortly after its emergence from the Gulf of Mexico.

In accordance with instructions issued by Hon. George R. Putnam, Commissioner, U. S. Bureau of Lighthouses, daily samples, with some omissions, were collected from Atlantic Ocean off Fowey Rocks, Florida, by the light-keeper from March 24, 1914, to October 17, 1915, under the direction of Dr. H. F. Moore of the U. S. Bureau of Fisheries. The samples were collected in 350 c.c. citrate of magnesia bottles about 18 inches below the surface and were shipped for examination as opportunity afforded to the laboratory at Washington, D. C. The chloride content of each sample was determined by titration, and the salinity and specific gravity were calculated from the result of this determination. These data, with the condition of the tide, the direction and velocity of the wind, and the condition of the weather as reported by the light-tender and the precipitation recorded at the station of the U. S. Weather Bureau at Miami, Florida, are given in the accompanying table. The determinations of chloride from March 12 to June 18, inclusive, 1914, were made by E. C. Bain; from June 19 to December 24, inclusive, 1914, by C. D. Parker; and from December 25, 1914, to October 17, 1915, inclusive, by A. A. Chambers. The results were computed and tabulated by Mr. Chambers.

[1] U. S. Coast and Goedetic Survey Coast chart No. 166, Florida Reefs, from Key Biscayne to Carysfort Reef.

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida.

Date of collection.[1] 1914–1915.	Condition of tide.[2]	Wind.[2] Direction.	Wind.[2] Velocity.	Condition of weather.[2]	Precipitation at Miami.[3]	Content of chloride.	Salinity.	Specific gravity (0/4)°.
					in.	*gms. per kg.*	*gms. per kg.*	
Mar. 12	Low	SE	Light	Hazy		19.95	36.04	1.02896
13								
14	High	E	Moderate	Hazy	0.72	19.90	35.95	1.02889
15	Falling	SE	Do.	Cloudy		19.93	36.00	1.02894
16	Do.	SE	Do.	Clear		19.96	36.06	1.02898
17	High	SE	Do.	Do.		19.95	36.04	1.02896
18								
19	Falling	SE	Moderate	Clear		19.98	36.09	1.02901
20								
21								
22	Rising	Variable	Moderate		.09	19.97	36.08	1.02899
23								
24								
25	Rising	NE	Strong	Rain		19.98	36.09	1.02901
26	Do.	NE	Moderate gale	Do.		19.99	36.11	1.02902
27[4]	High	SE	Strong	Do.		19.97	36.08	1.02899
28	Low	SE	Moderate	Cloudy		19.93	36.00	1.02894
29	Do.	SE	Do.	Clear		19.93	36.00	1.02894
30	Rising	SE	Fresh	Cloudy		19.92	35.99	1.02892
31	Do.	SE	Moderate	Clear		19.96	36.06	1.02898
Apr. 1					.08			
2	Falling	Variable	Fresh	Rain	2.96	19.96	36.06	1.02898
3	Do.	NW	Do.	Hazy	Trace.	19.92	35.99	1.02892
4	Do.	E	Light	Do.	.01	19.99	36.11	1.02902
5[5]	Low	Variable	Variable	Cloudy	.26	19.81	35.79	1.02876
6[6]	Falling	NE	Light	Do.	.79	19.79	35.75	1.02873
7[7]	Do.	NE	Do.	Rain	Trace.			
8	High	W	Do.	Cloudy		19.93	36.00	1.02894
9	Falling	S	Do.	Do.		19.86	35.88	1.02883
10	Do.	Variable		Rain	.13	19.86	35.88	1.02883
11	Low	S	Moderate	Clear		19.79	35.75	1.02873
12[7]	Rising	S	Do.	Do.		19.80	35.77	1.02875
13[8]	Do.	E	Do.	Cloudy	.36	19.86	35.88	1.02883
14								
15	Low	Variable		Showers	.16	19.81	35.79	1.02876
16[9]	Do.	N	Fresh	Cloudy		19.95	36.04	1.02896
17	Falling	NE		Clear		20.01	36.15	1.02905
18	Do.	NE		Do		19.89	35.93	1.02888
19	High	E		Hazy		19.88	35.91	1.02886
20	Falling	S		Do.	.49	19.76	35.70	1.02869
21	Low	NE	Breeze	Do.		19.88	35.91	1.02886
22	Falling	ENE		Do.		19.92	35.99	1.02892
23	Do.	E		Clear		19.88	35.91	1.02886
24	Low	E		Do.		19.92	35.99	1.02892
25[10]	High	E		Do.		19.93	36.00	1.02894
26	Low			Hazy		19.93	36.00	1.02894
27	Low	E		Clear		19.98	36.09	1.02901
28	Rising	SE	Moderate			19.82	35.81	1.02878
29	Do.	SW	Do.			19.97	36.08	1.02899
30	Falling	E		Clear		19.88	35.91	1.02886
May 1	Do.	E. to S.		Hazy	.16	19.97	36.08	1.02899
2								
3	Falling	E		Clear		19.99	36.11	1.02902
4	High	E		Do.		20.09	36.29	1.02917

[1]8 a. m. unless otherwise designated.
[2]Reported by light keeper at Fowey Rocks Light.
[3]Compiled from Weather Bureau, U. S. Dept. Agr., vol. 1, No. 3, to vol. 2, No. 10, inc., 1914–15.
[4]12 noon. [5]11 a. m. [6]9 a. m. [7]11.30 a. m. [8]10 a. m. [9]10.30 a. m. [10]7 a. m.

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914–1915.	Condition of tide.	Wind.		Condition of weather.	Precipitation at Miami.	Content of chloride.	Salinity.	Specific gravity (0/4)°.
		Direction.	Velocity.					
					in.	*gms. per kg.*	*gms. per kg.*	
May 5	High	E.........	....	Clear.........	....	20.02	36.17	1.02907
6	Rising.....	S.........	....	Hazy.........	....	20.15	36.40	1.02926
6	...Do......	SE........	....	Clear.........	....	20.03	36.18	1.02908
7	...Do......	S.........	....	.....Do.......	....	20.85	37.66	1.03028
8	...Do......	S.........	....	.....Do.......	....	19.64	35.48	1.02851
9	...Do......	SW........	....	Hazy.........	....	20.09	36.29	1.02917
10	...Do......	E.........	....	Clear.........	....	20.06	36.24	1.02912
11	Low.......	E.........	....	Hazy.........	....	20.03	36.18	1.02908
12	...Do......	E.........	....	Clear.........	....	20.04	36.20	1.02910
13	Rising.....	E.........	....	Hazy.........	....	20.21	36.51	1.02934
14	...Do......	SE.......	Moderate......	Rain..........	0.64	19.93	36.00	1.02894
15	...Do......	Variable...	....	.....Do.......	.14	19.98	36.09	1.02901
16	...Do......	E.........	Moderate......	Cloudy........	....	......	......	....
17	High.......	Variable...	....	Rain..........	.21	19.93	36.00	1.02894
18	Falling.....	E.........	Squally.......	....	....	19.98	36.09	1.02901
19	...Do......	NE.......	Fresh.........	Cloudy........	.16	19.98	36.09	1.02901
20	Low.......	NE.......	Strong........	Rain..........	.10	19.98	36.09	1.02901
21[1]	Rising.....	NE.......	.....Do.......	Cloudy........	....	19.95	36.04	1.02896
22[1]	...Do......	NE.......	Fresh.........	.....Do.......	....	19.95	36.04	1.02896
23	...Do......	NE.......	.....Do.......	.....Do.......	Trace.	19.98	36.09	1.02901
24	High.......	NE.......	.....Do.......	.....Do.......	.06	19.96	36.06	1.02898
25	Falling.....	NE.......	.....Do.......	.....Do.......	.24	19.98	36.09	1.02901
26	...Do......	NE.......	.....Do.......	Rain..........	.12	20.02	36.17	1.02907
27	...Do......	E.........	.....Do.......	Cloudy........	....	......	......	....
28	Low.......	NE.......	.....Do.......	.....Do.......	....	19.97	36.08	1.02899
29	Rising.....	NE.......	.....Do.......	.....Do.......	....	19.95	36.04	1.02896
30	...Do......	E.........	Moderate......	.....Do.......	....	19.99	36.11	1.02902
31	...Do......	E.........	.....Do.......	.....Do.......	....	20.01	36.15	1.02905
June 1	High.......	E.........	.....Do.......	.....Do.......	....	20.00	36.13	1.02904
2	Falling.....	ESE......	.....Do.......	Clear.........	....	19.99	36.11	1.02902
2	...Do......	ESE......	.....Do.......	.....Do.......	....	19.96	36.06	1.02898
3	...Do......	SE.......	Light.........	.....Do.......	....	19.95	36.04	1.02896
4	Low.......	SE.......	Fresh.........	Cloudy........	.01	19.95	36.04	1.02896
5	...Do......	SE.......	Moderate......	.....Do.......	....	19.95	36.04	1.02896
6	....	....	....	....	....	......	......	....
7	Rising.....	SE.......	Moderate......	Clear.........	....	20.04	36.20	1.02910
8	High.......	SE.......	.....Do.......	Cloudy........	....	19.95	36.04	1.02896
9	...Do......	E.........	.....Do.......	Clear.........	....	19.95	36.04	1.02896
10	Falling.....	Variable...	Light.........	Cloudy........	....	19.95	36.04	1.02896
11	...Do......	SE.......	.....Do.......	.....Do.......	1.13	19.95	36.04	1.02896
12	...Do......	SE.......	.....Do.......	.....Do.......	....	19.95	36.04	1.02896
13	Low.......	SE.......	.....Do.......	.....Do.......	....	......	......	....
14	...Do......	SE.......	Moderate......	.....Do.......	.02	20.13	36.36	1.02923
15	Rising.....	S.........	Light.........	.....Do.......	Trace.	19.97	36.08	1.02899
16	Falling.....	....	Calm.........	....	....	19.95	36.04	1.02896
17	....	....	....	....	....	......	......	....
18	Low.......	S.........	Light.........	Cloudy........	.79	19.98	36.09	1.02901
19	Rising.....	....	....	....	....	19.99	36.11	1.02902
20	...Do......	Variable...	Light.........	Cloudy........	.01	19.97	36.08	1.02899
21	...Do......	...Do.....	.....Do.......	.....Do.......	.37	20.06	36.24	1.02912
21	...Do......	....	Squally.......	.....Do.......		19.99	36.11	1.02902
22	...Do......	SE.......	Moderate......	.....Do.......	....	19.99	36.11	1.02902
23	...Do......	E.........	.....Do.......	.....Do.......	....	20.06	36.24	1.02912
24	High.......	SE.......	Light.........	.....Do.......	....	20.02	36.17	1.02907
25	Falling.....	SE.......	.....Do.......	.....Do.......	....	20.03	36.18	1.02908
26	...Do......	SE.......	.....Do.......	.....Do.......	....	20.03	36.18	1.02908
27	...Do......	SE.......	.....Do.......	.....Do.......	....	20.01	36.15	1.02905

[1] 9 a. m.

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914-1915	Condition of tide.	Wind.		Condition of weather.	Precipitation at Miami[2]	Content of chloride.	Salinity.	Specific gravity (0/4)°.
		Direction.	Velocity.					
					in.	*gms. per kg.*	*gms. per kg.*	
June 28	Falling	Variable.	Light...	Cloudy	0.16	20.03	36.18	1.02908
29	..Do..	E...	Do.	Clear...	.06	20.01	36.15	1.02905
30	..Do..	Variable.	Squally.		.02	20.01	36.15	1.02905
July 1	Low...	..Do...	Light	Do.	10	20.01	36.15	1.02905
2	...	...	...	...	65	...	...	...
3	Low...	SE.....	Light....	Cloudy...		19.94	36.02	1.02895
4	Rising..	E.......	....Do...	....Do.		19.93	36.00	1.02894
5	..Do..	Variable...	Moderate.	Clear..		19.93	36.00	1.02894
6	..Do..	.Do...	Squally..		.44	19.96	36.06	1.02898
7	High...	..Do...	....Do..		.85	19.95	36.04	1.02896
8	..Do..	..Do...		Rain.	.29	19.93	36.00	1.02894
9	Falling.	.Do...	Squally	...	.07	19.69	35.57	1.02859
10	..Do....	SE ...	Light...	.....	.04	19.68	35.55	1.02857
11	..Do....	SE	....Do..	Cloudy ...	.01	19.85	35.86	1.02882
12	...Do....	SE.....	..Do	Rain...	...	19.84	35.84	1.02880
13	..Do....	SE.....	Do ..	Cloudy...	1.18	19.85	35.86	1.02882
14	....	...	...	...	...	...	...	...
15	Low...	SE.. ...	Moderate....	Cloudy...	.16	19.83	35.82	1.02879
16	..Do....	E..	Light....	Rain...	.11	19.85	35.86	1.02882
17	Rising..	SE.	....Do...	Cloudy....		19.97	36.08	1.02899
18	.....	...	...	...	12	...	...	...
19	Falling....	SE...	Moderate......	Clear...	......	19.99	36.11	1.02902
20	Rising.....	SE.....	....Do......	Cloudy....	......	20.00	36.13	1.02904
21	High....	SE.....	....Do..	.....Do..	.04	19.99	36.11	1.02902
..	......	...	...	...	...	...	...	...
Sept. 12	Low.....	SE.......	...	Cloudy...	.72	19.69	35.57	1.02859
13	...Do.....	Variable...	Light..	...Do....	.80	19.72	35.62	1.02863
14	..Do....	N.	Fresh....	Hazy.......	...	19.75	35.68	1.02867
14	...Do.....	N........	....Do....	.....Do...	...	19.66	35.52	1.02854
15	Rising....	NE.......	....Do......	Cloudy.....	.01	19.89	35.93	1.02888
16	...Do....	N........	Strong....	.....Do...	...	19.89	35.93	1.02888
17	..Do...	W	Moderate.....	.....Do......	02	19.89	35.93	1.02888
18	High...	SE.....	Fresh.....	.....Do....	...	19.88	35.91	1.02886
19	..Do....	E.......	Moderate......	Clear....	.02	19.87	35.90	1.02885
20	...Do.....	E.........	...	.....Do....	.26	19.89	35.93	1.02888
21	Falling...	NE.....	...	Drizzling.	.17	19.94	36.02	1.02895
22	....	...	...	...	...	...	...	...
23	Rising.....	E........	...	Cloudy........	.15	19.88	35.91	1.02886
24	...Do.....	S.....	...	.....Do.......	...	19.89	35.93	1.02888
25	Low...	S.....	...	.....Do.......	...	19.93	36.00	1.02894
26	...Do....	Variable...	...	.....Do.....	...	19.93	36.00	1.02894
27	...Do....	E........	...	Clear.....	...	19.95	36.04	1.02896
28	Rising.....	E........	...	....Do....	...	19.93	36.00	1.02894
29	...Do....	E........	...	.....Do.....	.04	19.93	36.00	1.02894
29	...Do....	E........	...	Cloudy.......		19.86	35.88	1.02883
30	...Do.....	E.........	...	Clear... ...	.44	19.96	36.06	1.02898
Oct. 1	...Do.....	ENE.....	...	Cloudy....	.94	19.95	36.04	1.02896
2	High.......	Variable...	Squally.	....	.26	19.86	35.88	1.02883
3	...Do...	N		Rain....	.89	19.47	35.17	1.02827
4	...Do..	Variable...		.....Do..	1.74	19.67	35.53	1.02856
5	...Do....	S........		Cloudy.	10	19.64	35.48	1.02851
6	Rising.....	SE.....		....Do.......		19.66	35.52	1.02854
7	..Do....	...	Calm.	Hazy...	.02	19.68	35.55	1.02857
8	...Do. ...	SE.......	Light...	Clear...	.03	19.24	34.76	1.02793
9	....	...	...	...	...	...	...	...
10	Rising.....	E.....	Strong..	Rain....	...	19.02	34.36	1.02761
11	Low......	E.....	....	Clear...	...	19.89	35.93	1.02888
12	...Do.. ..	E ...	...	Do	.	19.86	35.88	1.02883

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914–1915.	Condition of tide.	Wind. Direction.	Wind. Velocity.	Condition of weather.	Precipitation at Miami.	Content of chloride.	Salinity.	Specific gravity (0/4)°
					in.	*gms. per kg.*	*gms. per kg.*	
Oct. 13	Rising	E		Cloudy	0.14	19.81	35.79	1.02876
14	Falling	E		Do	.68	19.93	36.00	1.02894
15	Do	E		Do	.01	19.58	35.37	1.02843
16	Do	SE		Do	.01	19.91	35.97	1.02891
17	Do	N		Do	.14	19.57	35.35	1.02841
18	Low	NE	Moderate	Do	Trace.	19.88	35.91	1.02886
19	Do	E	Do	Do	.39	19.87	35.90	1.02885
20	Rising	E	Do	Do	.19	19.79	35.75	1.02873
21	Do	E	Do	Do	.06	19.82	35.81	1.02878
22	Do	Variable	Light	Do	.20	19.73	35.64	1.02864
23	Do	Do	Do	Do		19.74	35.66	1.02866
24	Do	SE	Do	Do	.01	19.72	35.62	1.02863
25	High	E	Do	Rain	.72	19.72	35.62	1.02863
26	Do	Variable		Do	.36	19.71	35.61	1.02862
27	Falling	W	Moderate	Cloudy	.03	19.78	35.73	1.02872
28	Low	NE	Strong	Do		20.06	36.24	1.02912
29	Do	N	Fresh	Do		20.09	36.29	1.02917
30	Rising	N	Do	Do		20.06	36.24	1.02912
31	Do	E	Do	Do	Trace.	19.57	35.35	1.02841
Nov. 1	High	E	Moderate	Clear		19.87	35.90	1.02885
2	Do	ENE	Fresh	Hazy		19.96	36.06	1.02898
3	Do	E	Do	Cloudy		19.85	35.86	1.02882
4	Falling	ESE	Do	Do	.02	19.93	36.00	1.02894
5	Do	N	Do	Rain	.89	20.00	36.13	1.02904
6	Do	E	Do	Cloudy	.71	20.01	36.15	1.02905
7	Do	E	Do	Do	.05	20.03	36.18	1.02908
8	Do	Variable	Strong	Do	4.71	20.03	36.18	1.02908
9	Low	N	Fresh	Hazy	.09	20.00	36.13	1.02904
10	Rising	N	Do	Do		19.35	34.96	1.02809
11	Do	NE	Do	Do	.04	19.33	34.92	1.02806
12	Do	E	Do	Do	.04	19.36	34.97	1.02811
13	Do	E	Moderate	Cloudy		19.35	34.96	1.02809
14	Do	E	Strong	Do	.31	19.33	34.92	1.02806
15	High	SW	Moderate	Do	Trace.	19.35	34.96	1.02809
16	Do	SW	Light	Do		20.00	36.13	1.02904
17	Falling	E	Moderate	Hazy		19.96	36.06	1.02898
18	Do	NE	Fresh	Cloudy		19.97	36.08	1.02899
19	Low	N	Do	Hazy		19.99	36.11	1.02902
20	Do	N	Moderate	Clear		20.00	36.13	1.02904
21	Rising	N	Do	Do		20.02	36.17	1.02907
22	Do	NE	Do	Cloudy		20.04	36.20	1.02910
23	Do	E	Fresh	Hazy		20.00	36.13	1.02904
24	Do	E	Strong	Cloudy	.20	20.00	36.13	1.02904
25	Do	E	Fresh	Do		20.00	36.13	1.02904
26	Do	E	Do	Do		20.04	36.20	1.02910
27	High	SE	Do	Do		20.02	36.17	1.02907
28	Do	SE	Do	Do		20.11	36.33	1.02920
29	Falling	E	Do	Do		20.06	36.24	1.02912
30	Do	E	Do	Do	Trace.	20.08	36.27	1.02915
Dec. 1	Low	SE	Light	Do		19.99	36.11	1.02902
2	Do	Variable	Do	Hazy		20.09	36.29	1.02917
3	Rising	S	Do	Clear		20.02	36.17	1.02907
4	Do	S	Do	Do		20.02	36.17	1.02907
5	Do	S	Do	Do		19.98	36.09	1.02901
6	High	N	Moderate	Hazy		20.00	36.13	1.02904
7	Do	N	Do	Do		20.04	36.20	1.02910
8	Falling	Variable	Do	Cloudy		19.80	35.77	1.02875
9	Low	Do	Do	Do	.12	19.87	35.90	1.02885

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914–1915.	Condition of tide.	Wind.		Condition of weather.	Precipitation at Miami.	Content of chloride.	Salinity.	Specific gravity (0/4)°.
		Direction.	Velocity.					
					in.	*gms. per kg.*	*gms. per kg.*	
Dec. 10	Low	N	Moderate	Hazy	0.01	19.92	35.99	1.02892
11	Rising	N	Fresh	Do		19.93	36.00	1.02894
12	Do	N	Moderate	Do		20.00	36.13	1.02904
13	Do	N	Fresh	Cloudy	.03	20.02	36.17	1.02907
14	Do	N	Do	Hazy	1.23	.....	......	....
15	Do	N	Do	Do	.06	20.02	36.17	1.02907
16	High	NE. gale	Do	Rain	1.04	19.92	35.99	1.02892
17	Do	Variable	Do	Cloudy	.02	19.89	35.93	1.02888
18	Falling	E	Do	Do	.52	19.01	34.34	1.02760
19	Do	SE	Moderate	Do		19.01	34.34	1.02760
20	Low	SE	Do	Do		19.01	34.34	1.02760
21	Do	SE	Do	Do		19.01	34.34	1.02760
22	Rising	NE	Do	Foggy		19.01	34.34	1.02760
23	Do	NE	Do	Do	.02	19.99	36.11	1.02902
24	High	Variable	Do	Hazy	.02	19.01	34.34	1.02760
25	Falling	SE	Fresh	Cloudy		19.92	35.98	1.02892
26	Do	SE	Do	Do	.60	19.91	35.97	1.02891
27	Half-tide	Variable	Light	Rain	Trace.	19.92	35.98	1.02892
28	Falling	SE	Moderate	Cloudy	.19	20.01	36.15	1.02905
29	Do	SE	Fresh	Do		20.00	36.13	1.02904
30	Low	N	Do	Rain	.45	19.80	35.77	1.02875
31	Do	N	Do	Do	.12	19.79	35.75	1.02873
Jan. 1	Rising	N	Moderate	Foggy	.10	19.80	35.77	1.02875
2	Do	N	Fresh	Hazy		19.92	35.98	1.02892
3	Do	E	Do	Do		19.92	35.98	1.02892
4	Half-tide	E	Do	Cloudy	.54	20.05	36.22	1.02911
5	Rising	E	Do	Rain	.29	20.06	36.24	1.02912
6	High	E	Do	Cloudy	.06	20.03	36.18	1.02908
7	Do	N	Moderate	Hazy	.01	20.04	36.20	1.02912
8	Falling	N	Do	Do		20.10	36.31	1.02918
9	Do	NE	Fresh	Cloudy	.01	19.85	35.86	1.02882
10	Half-tide	NE	Do	Do		19.92	35.98	1.02892
11	Falling	E	Moderate gale	Do	.53	19.90	35.95	1.02889
12	Do	NW	Do	Do	.01	19.91	35.97	1.02891
13	Low	N	Fresh	Hazy		19.79	35.75	1.02873
14	Do	N	Moderate	Do		19.88	35.91	1.02886
15	Rising	N	Do	Do		19.84	35.84	1.02880
16	Do	E	Fresh	Cloudy		19.86	35.88	1.02883
17	High	SE	Moderate gale	Do	Trace.	19.91	35.97	1.02891
18	Do	SE	Strong	Do	.16	19.92	35.98	1.02892
19	Falling	N	Fresh	Rain	.96	19.88	35.91	1.02886
20	Do	N	Moderate	Clear		19.87	35.90	1.02885
21	Half-tide	N	Do	Hazy		19.89	35.93	1.02888
22	Falling	NE	Fresh	Cloudy		19.87	35.90	1.02885
23	Do	E	Do	Do	.06	19.88	35.91	1.02886
24	Do	E	Do	Do	.21	.....	......	....
25	Low	S	Moderate	Rain	.60	19.88	35.91	1.02886
26	Do	N	Do	Do	Trace.	19.85	35.86	1.02882
27	Do	E	Fresh	Cloudy	.10	19.83	35.82	1.02879
28	Rising	N		Do		19.90	35.95	1.02889
29	Do	NE		Do	Trace.	19.92	35.98	1.02892
30	High	ENE		Do		.....	......	....
31	Do	ESE		Do		19.94	36.02	1.02895
Feb. 1	Falling	SE	Gale		Trace.	19.92	35.98	1.02892
2	Do	Variable		Cloudy	.14	19.92	35.98	1.02892
3	Half-tide	N		Clear		19.87	35.90	1.02885
4	Low	NE		Do		19.83	35.82	1.02879
5	Do	ESE		Cloudy		19.90	35.95	1.02889

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914–1915.	Condition of tide.	Wind. Direction.	Wind. Velocity.	Condition of weather.	Precipitation at Miami.	Content of chloride.	Salinity.	Specific gravity (0/4)°.
					in.	*gms. per kg.*	*gms. per kg.*	
Feb. 6	Rising	SE		Cloudy, hazy	0.54	19.97	36.08	1.02899
7	Do	N		Overcast	.03	20.00	36.13	1.02904
8	Falling	N		Part clear		20.00	36.13	1.02904
9	Do	N		Clear		19.97	36.08	1.02899
10	Do	N		Part clear	Trace.	19.98	36.09	1.02901
11	Half-tide	NE	Gale	Do		19.99	36.11	1.02902
12	Falling	NE		Clear	Trace.	19.98	36.09	1.02901
13	Do	E		Part clear		20.01	36.15	1.02905
14	High water	E		Cloudy		20.01	36.15	1.02905
15	Rising	E		Do	Trace.	20.03	36.18	1.02908
16	Rising	SE		Heavy rain	1.96	20.01	36.15	1.02905
17	Half-tide	N		Part clear		20.02	36.17	1.02907
18	Rising	N		Hazy		19.93	36.00	1.02894
19	Do	NE		Hazy and clear	.02	19.94	36.02	1.02895
20	Do	NE		Part clear	.03	19.92	35.98	1.02892
21	Low water	NE		Do		19.91	35.97	1.02891
22	Do	E	Gale	Cloudy		19.90	35.95	1.02889
23	Do	E	Do	Overcast	Trace.	19.91	35.97	1.02891
24	Rising	SW		Cloudy to clear	.29	19.92	35.98	1.02892
25	Falling	NW		Clear				
26	Do	N		Clear, hazy		19.92	35.98	1.02892
27	Do	SE	Light	Clear		19.92	35.98	1.02892
28	Do	SW		Cloudy		19.92	35.98	1.02892
Mar. 1	Low	N	Moderate	Do		19.92	35.98	1.02892
2	Do	E	Light	Clear				
3	Rising	SE	Moderate	Cloudy		19.92	35.98	1.02892
4	Do	SE	Light	Clear		19.94	36.02	1.02895
5	Half-tide	Variable	Fresh	Cloudy	.49	19.92	35.98	1.02892
6	Rising	N	Moderate	Hazy	.02	19.93	36.00	1.02894
7	Do	N	Light	Clear		19.92	35.98	1.02892
8	High	N	Fresh	Hazy		19.94	36.02	1.02895
9	Do	N	Do	Do		19.92	35.98	1.02892
10	Falling	NE	Light	Do		19.92	35.98	1.02892
11	Do	NE	Do	Do		19.93	36.00	1.02894
12	Low	Variable	Do	Fog		19.94	36.02	1 02895
13	Do	E	Moderate	Hazy	.31	19.93	36.00	1.02894
14	Half-tide	SE	Do	Cloudy	.08	19.95	36.04	1.02896
15	Falling	N	Fresh	Hazy		19.90	35.95	1.02889
16	Do	NW	Do	Do	Trace.	19.96	36.06	1.02898
17	Half-tide	N	Do	Do		20.01	36.15	1.02905
18	Falling	N	Do	Do		19.96	36.06	1.02898
19	Do	N	Do	Rain	.25	19.95	36.04	1.02896
20	Low	Calm	Calm	Clear		19.96	36.06	1.02898
21	Do	N	Moderate	Do		19.96	36.06	1.02898
22	Rising	N	Fresh	Rain	.42	19.94	36.02	1.02895
23	Do	N	Do	Hazy		19.94	36.02	1.02895
24	Half-tide	W	Moderate	Do	Trace.	19.94	36.02	1.02895
25	Rising	N	Do	Clear		19.97	36.08	1.02899
26	Do	NE	Do	Cloudy		19.96	36.06	1.02898
27	High	E	Do	Do		19.95	36.04	1.02896
28	Do	N	Do	Clear		19.94	36.02	1.02895
29	Falling	N	Do	Do		19.98	36.09	1.02901
30	Do	W	Do	Do		19.87	35.90	1.02885
31	Half-tide	N	Do	Do		19.85	35.86	1.02882
Apr. 1	Do	E	Do	Do	.01	19.84	35.84	1.02880
2	Falling	SW	Squally	Cloudy	.59	19.95	36.04	1.02896
3	Low	NW	Moderate gale	Hazy	Trace.	19.99	36.11	1.02902
4	Do	N	Fresh	Do		19.96	36.06	1.02898

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914–1915	Condition of tide.	Wind.		Condition of weather.	Precipitation at Miami	Content of chloride	Salinity.	Specific gravity (0/4)°.
		Direction.	Velocity.					
					in.	gms. per kg.	gms. per kg.	
April 5	Rising	NE	Fresh	Cloudy		19.97	36.08	1.02899
6	...Do	E	....Do	....Do		19.98	36.09	1.02901
7	Half-tide	SE	....Do	....Do		19.99	36.11	1.02902
8	Rising	E	Moderate	....Do		19.99	36.11	1.02902
9	...Do	E	Fresh	....Do		20.01	36.15	1.02905
10	High	E	.....Do	....Do		20.03	36.18	1.02908
11	...Do	SE	Strong	....Do	Trace.	20.05	36.22	1.02911
12	Falling	SE	Moderate	....Do		20.06	36.24	1.02912
13	...Do	NE	.....Do	....Do	Trace.	20.03	36.18	1.02908
14	Half-tide	NE	Strong	....Do	0.01	20.01	36.15	1.02905
15	Falling	NE	Moderate	Rain	.33	20.00	36.13	1.02904
16	...Do	N	Fresh	Cloudy		19.98	36.09	1.02901
17	Low	N	.....Do	Hazy		20.01	36.15	1.02905
18	...Do	N	Moderate	Foggy		20.03	36.18	1.02908
19	Rising	E	.....Do	.....Do		20.02	36.17	1.02907
20	...Do	SE	.....Do	.....Do		19.95	36.04	1.02896
21	Half-tide	SE	.....Do	Cloudy		19.91	35.97	1.02891
22	Rising	SE	Fresh	.....Do		19.99	36.11	1.02902
23	...Do	SE	Strong	.....Do		20.01	36.15	1.02905
24	High	SE	Fresh	.....Do		20.00	36.13	1.02904
25	...Do	SE	.....Do	.....Do	.02	19.98	36.09	1.02901
26	Falling	SE	.....Do	.....Do		19.98	36.09	1.02901
27	...Do	SE	....Do	.....Do		19.98	36.09	1.02901
28	Half-tide	SE	Moderate	.....Do		20.00	36.13	1.02904
29	Falling	SE	.....Do	.....Do	.36	20.00	36.13	1.02904
30	...Do	W	.....Do	.....Do		19.99	36.11	1.02902
May 1	Low	W	....Do	Hazy		19.91	35.97	1.02891
2	...Do	NE	Light	.....Do		20.00	36.13	1.02904
3	Rising	E	.....Do	.....Do		19.69	35.57	1.02859
4	...Do	SE	Moderate	Cloudy		20.07	36.26	1.02914
5	Half-tide	SE	Light	Hazy		19.99	36.11	1.02902
6	Rising	SE	....Do	....Do		19.98	36.09	1.02901
7	...Do	SE	Moderate	....Do		20.00	36.13	1.02904
8	High	SE	Fresh	Cloudy		20.02	36.17	1.02907
9	..Do	SE	Moderate	....Do		20.02	36.17	1.02907
10	Falling	SE	.....Do	.....Do		20.02	36.17	1.02907
11	..Do	E	Fresh	....Do	.02	20.15	36.40	1.02926
12	Half-tide	E	....Do	....Do		20.05	36.22	1.02911
13	Falling	SE	....Do	.....Do	.24	20.03	36.18	1.02908
14	...Do	SE	Light	.....Do	.08	20.00	36.13	1.02904
15	Low	SE	Moderate	Squally		20.06	36.24	1.02912
16	...Do	SE	Light	Cloudy		20.02	36.17	1.02907
17	...Do	SE	Moderate	Clear		20.05	36.22	1.02911
18	Rising	Variable	Squally	Rain	.81	20.04	36.20	1.02910
19	...Do	...Do	.....Do	Cloudy		20.00	36.13	1.02904
20	Half-tide	SE	Light	....Do		20.01	36.15	1.02905
21	Rising	SE	Moderate	.....Do		20.04	36.20	1.02910
22	...Do	E	.....Do	.....Do		20.06	36.24	1.02912
23	High-tide	E	.....Do	....Do		20.03	36.18	1.02908
24	...Do	E	Light	....Do		20.06	36.24	1.02912
25	Falling	E	.....Do	.....Do		20.06	36.24	1.02912
26	...Do	SE	.....Do	....Do		20.02	36.17	1.02907
27	Half-tide	SE	Moderate	Hazy		20.06	36.24	1.02912
28	Falling	SE	....Do	Cloudy		20.02	36.17	1.02907
29	...Do	Variable	....Do	.....Do	1.38	20.03	36.18	1.02908
30	Half-tide	SE	....Do	.....Do	.11	20.03	36.18	1.02908
31	Falling	SE	....Do	.....Do	.68	20.01	36.15	1.02905
June 1	...Do				2.69	19.79	35.75	1.02873

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914–1915.	Condition of tide.	Wind.		Condition of weather.	Precipitation at Miami.	Content of chloride.	Salinity.	Specific gravity (0,4)°.
		Direction.	Velocity.					
					in.	*gms. per kg.*	*gms. per kg.*	
June 2	Low				2.26	19.68	35.55	1.02857
3	Do				.28	19.47	35.17	1.02827
4	Rising	ENE	Moderate	Clear		19.70	35.59	1.02860
5	Do	E		Do		19.82	35.81	1.02878
6	Half-tide	E	Moderate	Do		19.77	35.71	1.02870
7	Rising	E		Do		19.65	35.50	1.02853
8	Do	E	Light air	Do		19.83	35.82	1.02879
9	High	ESE	Light	Do		19.80	35.77	1.02875
10	Do	ESE		Do		19.81	35.79	1.02876
11	Falling	E		Do		19.82	35.81	1.02878
12	Do	E		Do		19.75	35.68	1.02867
13	High	ENE	Squally		.86	19.80	35.77	1.02875
14	Do	ESE	Fresh	Cloudy	1.38	21.37	38.60	1.03103
15	Falling	E	Squally		.02	19.97	36.08	1.02899
16	Do	E	Gale	Drizzling rain	1.32	21.61	39.04	1.03138
17	Do	SE	Strong	Hazy	3.10	19.65	35.50	1.02853
18	Rising				Trace.	19.18	34.65	1.02784
19	Do	E		Clear	.06	19.17	34.64	1.02783
20	Do	E		Do		19.61	35.43	1.02847
21	Do	E	Light	Do		19.56	35.34	1.02840
22	Low	E		Do		19.83	35.82	1.02879
23	Do	Variable		Cloudy	Trace.	20.21	36.51	1.02934
24	Rising		Squally	Rain	.20	19.73	35.64	1.02864
25	Falling			Overcast	.36	19.87	35.90	1.02885
26	Half-tide		Light air	Clear	Trace.	19.69	35.57	1.02859
27	Falling	Calm	Calm	Do		19.03	34.38	1.02763
28	High water	Variable	Light	Do		19.54	35.30	1.02837
29	High	Calm	Calm	Overcast		19.90	35.95	1.02889
30	Falling	SE	Light	Cloudy		19.82	35.81	1.02878
July 1	Rising	Calm	Calm			20.03	36.18	1.02908
2	Falling	SE	Moderate	Cloudy	Trace.	19.86	35.88	1.02883
3	Half-tide	E	Fresh	Clear		20.02	36.17	1.02907
4	Falling	E	Do	Cloudy	.05	20.01	36.15	1.02905
5	Do	SE	Moderate	Clear	.17	20.03	36.18	1.02908
6	Half-tide	SE	Do	Cloudy		20.05	36.22	1.02911
7	Falling	SE	Do	Do		20.01	36.15	1.02905
8	Do	SE	Do	Do		20.01	36.15	1.02905
9	Low	SE	Do	Do		20.00	36.13	1.02904
10	Do	SE	Do	Do	Trace.	19.95	36.04	1.02896
11	Rising	SE	Do	Do		19.95	36.04	1.02896
12	Do	SE	Light	Do		19.99	36.11	1.02902
13	Do	SE	Do	Do	.07	19.83	35.82	1.02879
14	Do	SE	Do	Do		19.94	36.02	1.02895
15	High	SE	Do	Clear		20.14	36.38	1.02924
16	Do	SE	Do	Cloudy		19.95	36.04	1.02896
17	Falling	Variable	Moderate	Do		20.05	36.22	1.02911
18	Do	SW	Light	Clear		19.97	36.08	1.02899
19	Half-tide	SE	Do	Cloudy		20.00	36.13	1.02904
20	Do	SE	Do	Do	.09	19.94	36.02	1.02895
21	Do	SE	Do	Do	.49	19.95	36.04	1.02896
22	Rising	Variable		Rain	.02	19.90	35.95	1.02889
23	Do	Do		Do	.07	19.91	35.97	1.02891
24	High	Do	Squally	Cloudy	.36	19.92	35.99	1.02892
25	Do	SE	Moderate	Do	1.10	19.91	35.97	1.02891
26	Falling	SE	Light	Do	.38	19.96	36.06	1.02898
27	Do	SE	Do	Rain	1.09	19.94	36.02	1.02895
28	Half-tide	Variable	Squally	Do	1.30	19.88	35.91	1.02886
29	Do	Do	Light	Do	.33	19.82	35.81	1.02878

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914-1915.	Condition of tide.	Wind. Direction.	Wind. Velocity.	Condition of weather.	Precipitation at Miami.	Content of chloride.	Salinity.	Specific gravity (0/4)°.
					in.	*gms. per kg.*	*gms. per kg.*	
July 30	Half-tide...	Variable ..	Light squalls...	Cloudy........	0.03	19.85	35.86	1.02882
31	Falling.....	W........	Moderate......	.....Do.......	.99	....	....	....
Aug. 1	...Do......	SW.......	.....Do.......	Rain..........	.45	19.85	35.86	1.02882
2	Half-tide...	SE.......	Fresh.........	Cloudy........	....	19.81	35.79	1.02876
3	...Do......	SE.......	Moderate......	.....Do.......	Trace.	19.91	35.97	1.02891
4	Falling.....	SE.......	Fresh.........	.....Do.......	....	19.76	35.70	1.02869
5	...Do......	SE.......	Moderate......	.....Do.......	....	19.14	34.58	1.02779
6	Low.......	E.........	.....Do.......	.....Do.......	Trace.	19.14	34.58	1.02779
7	...Do......	E.........	.....Do.......	.....Do.......	.23	19.33	34.92	1.02806
8	...Do......	NE.......	.....Do.......	.....Do.......	....	19.34	34.94	1.02808
9	Rising.....	E.........	Light.........	.....Do.......	....	19.61	35.43	1.02847
10	....	....	....	....	....	....	....	....
11	Half-tide...	E.........	Moderate......	Cloudy........	Trace.	19.75	35.68	1.02867
12	...Do......	E.........	.....Do.......	.....Do.......	....	19.71	35.61	1.02862
13	....	....	....	....	....	....	....	....
14	Rising.....	E.........	Fresh gale.....	Cloudy........	....	19.70	35.59	1.02860
15	High.......	E.........	.....Do.......	.....Do.......	.20	19.70	35.59	1.02860
16	...Do......	SE.......	Moderate......	.....Do.......	....	19.67	35.53	1.02856
17	....	....	....	....	....	....	....	....
18	Half-tide...	SE.......	Moderate......	Clear.........	....	19.78	35.73	1.02872
19	....	....	....	....	....	....	....	....
20	Rising.....	Variable. .	Moderate......	Hazy.........	....	19.85	35.86	1.02882
21	High.......	ENE.....	Light.........	Cloudy........	....	19.81	35.79	1.02876
22	...Do......	E.........	....	.....Do.......	....	19.79	35.75	1.02873
23	Falling.....	E.........	....	Clear.........	....	19.79	35.75	1.02873
24	...Do......	E.........	....	Hazy.........	....	19.80	35.77	1.02875
25	...Do......	Variable...	....	Cloudy........	....	19.80	35.77	1.02875
26	Half-tide...	Calm.....	Calm.........	Hazy.........	....	19.80	35.77	1.02875
27	...Do......	....	....	....	....	19.81	35.79	1.02876
28	Falling.....	S.........	Light breeze...	Hazy.........	....	19.85	35.86	1.02882
29	Low.......	....	....	....	Trace.	19.85	35.86	1.02882
30	...Do......	E.........	Moderate......	Cloudy........	.06	19.85	35.86	1.02882
31	Rising.....	SE.......	Light.........	.....Do.......	.43	19.85	35.86	1.02882
Sept. 1	...Do......	Variable...	Variable.......	.....Do.......	.14	19.87	35.90	1.02885
2	Half-tide...	E.........	Moderate......	.....Do.......	1.22	19.85	35.86	1.02882
3	...Do......	E.........	Squally.......	.....Do.......	.45	19.80	35.77	1.02875
4	Rising.....	S.........	Fresh.........	.....Do.......	Trace.	19.81	35.79	1.02876
5	....	....	....	....	....	....	....	....
6	High.......	SE.......	Light.........	Clear.........	....	19.87	35.90	1.02885
7	...Do......	ENE.....	.....Do.......	Cloudy........	.16	19.89	35.93	1.02888
8	Falling.....	E.........	Light breeze...	Clear.........	....	19.88	35.91	1.02886
9	...Do......	E.........	Light.........	Cloudy........	....	19.91	35.97	1.02891
10	Half-tide...	E.........	Moderate......	.....Do.......	.06	19.89	35.93	1.02888
11	...Do......	E.........	.....Do.......	.....Do.......	.01	19.88	35.91	1.02886
12	...Do......	E.........	Light.........	.....Do.......	Trace.	19.77	35.71	1.02870
13	Falling.....	E.........	Moderate......	.....Do.......	.08	19.77	35.71	1.02870
14	...Do......	E.........	Fresh.........	.....Do.......	.13	19.76	35.70	1.02869
15	Low.......	E.........	Squally.......	Rain..........	1.67	19.49	35.21	1.02830
16	...Do......	E.........	Stormy........	.....Do.......	.44	19.71	35.61	1.02862
17	...Do......	E.........	Fresh.........	Cloudy........	....	19.71	35.61	1.02862
18	Rising.....	E.........	Light.........	.....Do.......	.03	19.61	35.43	1.02847
19	....	....	....	....	....	....	....	....
20	Rising.....	SE.......	Light.........	Cloudy........	....	18.91	34.16	1.02745
21	Half-tide...	SE.......	.....Do.......	.....Do.......	....	19.69	35.57	1.02859
22	Rising.....	SE.......	.....Do.......	Hazy.........	....	19.78	35.73	1.02872
23	...Do......	NE.......	Moderate......	Cloudy........	....	19.72	35.62	1.02863
24	High.......	E.........	Squally.......	....	....	19.72	35.62	1.02863
25	...Do......	E.........	Strong breeze..	Cloudy........	.65	19.71	35.61	1.02862

Content of chloride, salinity, and specific gravity of ocean-water at Fowey Rocks, Florida—Con.

Date of collection. 1914–1915.	Condition of tide.	Wind. Direction.	Wind. Velocity.	Condition of weather.	Precipitation at Miami.	Content of chloride.	Salinity.	Specific gravity (0/4)°.
					in.	*gms. per kg.*	*gms. per kg.*	
Sept. 26	Falling	E	Strong	Cloudy	0.01	19.71	35.61	1.02862
27	...Do	E	Fresh	.....Do	.16	19.71	35.61	1.02862
28	...Do	E	.....Do	Rain	.26	19.65	35.50	1.02853
29	Half-tide	ESE	Strong	Cloudy	....	19.73	35.64	1.02864
30	Falling	ESE	Fresh	.....Do	....	19.80	35.77	1.02875
Oct. 1	...Do	SE	.....Do	.....Do	....	19.83	35.82	1.02879
2	Low	SE	Light	.....Do	.31	19.83	35.82	1.02879
3	...Do	SE	.....Do	.....Do	....	....	....	....
4	Rising	SE	Moderate	.....Do	.29	19.84	35.84	1.02880
5	...Do	SE	Light	.....Do	.14	19.93	36.00	1.02894
6	Half-tide	SE	Light breeze	.....Do	....	19.92	35.99	1.02892
7	...Do	SE	Squally	.....Do	Trace.	19.92	35.99	1.02892
8	Rising	SE	Light	.....Do	.01	19.96	36.06	1.02898
9	High	N	....	.....Do	.63	20.04	36.20	1.02910
10	...Do	NE	Gale	Overcast	....	19.98	36.09	1.02901
11	Falling	NE	.....Do	Cloudy	Trace.	20.00	36.13	1.02904
12	Rising	E	Strong	Partly clear	.04	20.00	36.13	1.02904
13	...Do	E	Light	Clear	....	19.99	36.11	1.02902
14	...Do	Calm	Calm	.....Do	.34	19.93	36.00	1.02894
15	...Do	E	Light	.....Do	.02	19.91	35.97	1.02891
16	...Do	E	.....Do	.....Do	.01	19.90	35.95	1.02889
17	Low	E	....	.....Do	.39	19.92	35.99	1.02892

DETERMINATION OF CHLORIDE.

Chloride was estimated by titrating a measured sample of sea-water with a solution of silver nitrate in the presence of potassium chromate indicator by means of the salinity outfit supplied by the Copenhagen Laboratory of the Conseil permanent international de la Mer. Use of this apparatus was obtained through the courtesy of the United States Bureau of Fisheries. An essential part of the apparatus is a calibrated burette so graduated that its reading is approximately grams per kilogram of chloride if 15 cubic centimeters of sea-water is titrated with a solution containing about 37 grams per liter of silver nitrate. A float in the burette assists in estimating tenths of the smallest divisions. The strength of the standard solution of silver nitrate is determined by carefully analyzed sealed tubes of standard sea-water supplied by the Copenhagen Laboratory as a necessary part of the outfit. The apparatus is designed and constructed with the object of attaining maximum accuracy in titration. Special precautions observed in titration are precise measurement of the sample in an automatic pipette, vigorous stirring of the liquid by means of a glass rod flattened at the end, and observation of exactly similar tints as end-points.

CALCULATION OF RESULTS.

The results of the titrations were corrected and calculated by means of Knudsen's tables.[1] The corrections for removing the error caused by the difference in volume of equal weights of sea-waters of different salinity are applied as follows:

[1] Knudsen, Martin, Hydrographic tables, Copenhagen, 1901.

If N = chloride content of standard sea-water in grams per kilogram, A = reading of burette with standard sea-water, and a = reading of burette with sample, then $N - A = \alpha$, which may be defined as the deviation of the standard silver nitrate from the standard sea-water. Corrections k corresponding to the values α at various concentrations a are then ascertained from Knudsen's tables and are added to the reading of the burette in order to obtain the correct content of chloride in grams per kilogram.

The salinity S in grams per kilogram has been calculated by Knudsen by means of the formula $S = 0.030 + 1.8050$ Cl, and Knudsen's values have been given for the calculated salinity corresponding to the content of chloride of each sample.

Similarly Knudsen's values for density at 0° C. referred to distilled water at 4° C. (s_0) have been given. His formula for calculating density is:

$$s_0 = 1 + \frac{\sigma_0}{1000}$$

in which σ_0 is computed by the formula

$$\sigma_0 = -0.069 + 1.4708\,\mathrm{Cl} - 0.001570\,\mathrm{Cl}^2 + 0.0000398\,\mathrm{Cl}^3$$

ACCURACY OF RESULTS.

The discussion of the determinations has been limited to the period September 12, 1914, to October 17, 1915, inclusive, as the hiatus in the summer of 1914 makes it difficult to correlate the earlier estimates. The average content of chloride for the 388 determinations, September 12, 1914, to October 17, 1915, is 19.87 grams per kilogram. The average deviation of individual observations is ±0.15. The deviation in 246 determinations is greater than the average, and in 131 determinations less than the average, while in 11 determinations the deviation is zero. In a series of 100 duplicate titrations, many on different days and by two observers, the average deviation of individual observations is ±0.01 and exceeds 0.02 in only 5 titrations, while the deviation of 32 titrations was zero. The probable error of individual titrations certainly is less than 0.03 and the reasonable maximum deviation is less than 0.05. It is therefore reasonable to conclude, in view of the relative accuracy of the determinations of chloride and the remarkable excess of small plus deviations, that the sea-water at Fowey Rocks has a certain normal salinity, below which it falls frequently because of certain recurring influences that result in local intermittent dilution. The highest recorded contents of chloride are 21.37 grams per kilogram (June 14) and 21.61 grams per kilogram (June 16) during a period of heavy precipitation. These two estimates exceed the others so markedly without apparent reason that some suspicion is aroused regarding the samples, which were examined in triplicate. Only one other estimate exceeds the average more than 0.30 and only 7 others exceed it by more than 0.20 gram. On the other hand, 57 estimates are less than the average by 0.15 or more, 27 by 0.30 or more, and 14 by more than 0.60 gram.

DILUTING EFFECT OF PRECIPITATION.

The most apparent phenomenon that decreases the salinity of the water is precipitation, which dilutes the ocean-water to an uncertain depth. The comparison of the precipitation recorded at the climatological station in Miami with the content of chloride of the water at Fowey Rocks, graphically represented in figure 5, shows that precipitation at Miami is almost invariably followed within 24 hours by reduction of content of chloride at Fowey Rocks. Some selected examples bring this out more clearly. The average content of chloride for the period September 12, 1914, to October 17, 1915, inclusive, is 19.87 grams per kilogram. Practically no precipitation was recorded from October 27 to November 4, 1914, inclusive, and the content of chloride ranged from 19.57 to 20.09 grams per kilogram. The total precipitation from November 5 to 14, was 6.84 inches, the precipitation

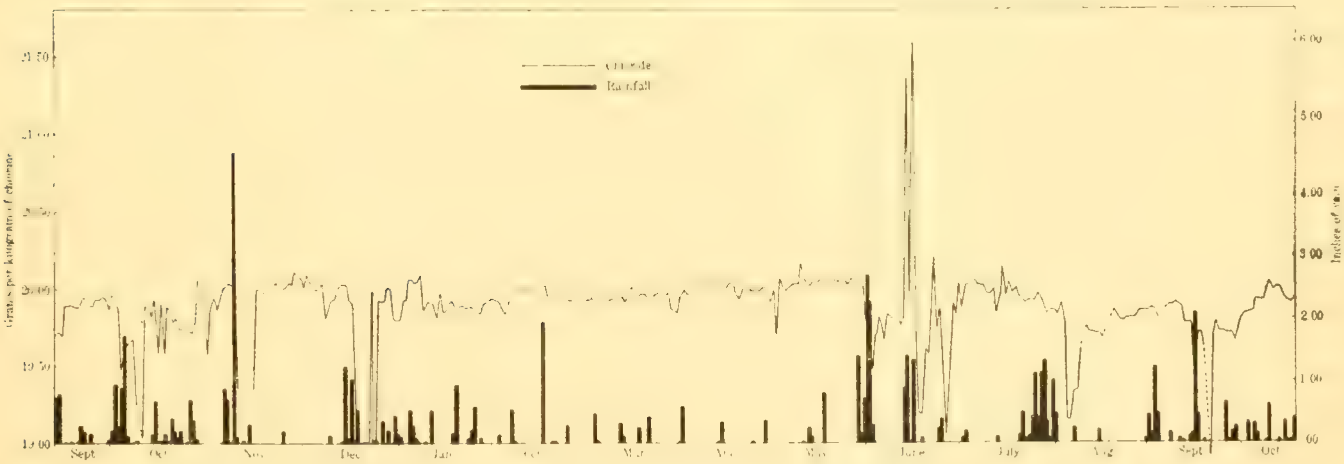


Fig. 5.—Graph showing daily content of chloride of sea-water at Fowey Rocks and daily precipitation at Miami, Florida, September 12, 1914, to October 17, 1915.

on November 8 having been 4.71 inches; the content of chloride fell from 20.00 grams on November 9 to 19.35 grams on November 10, where it remained till November 16 during a period of practically no precipitation. On the other hand, the total precipitation from November 14 to December 13, inclusive, was only 0.36 inch and from November 16 to December 15, inclusive, the chloride content ranged between 19.80 and 20.11, and averaged 20.00.

The quantitative effect of precipitation on the content of chloride is not entirely regular, for it is complicated by the effects of tide, wind, and current. For example, the total precipitation of 2.87 inches during December 14 to 18, inclusive, 1914, was accompanied by a reduction of chloride from 20.02 grams on December 15 to 19.01 grams during December 18 to 22, inclusive. A precipitation of 1.96 inches on February 16, 1915, however, was followed by a reduction of chloride from 20.03 on February 15 to 19.93 on February 18. The precipitation from July 20 to 31, inclusive, was 6.25 inches, and this was followed by a reduction of the content of

chloride from 20.00 grams per kilogram on July 19 gradually to 19.90 grams July 22, 19.82 grams July 29, and 19.14 grams August 5. The relation between content of chloride and precipitation is indicated by periods in more detail in the following table, and it is graphically shown by figures 5 and 6.

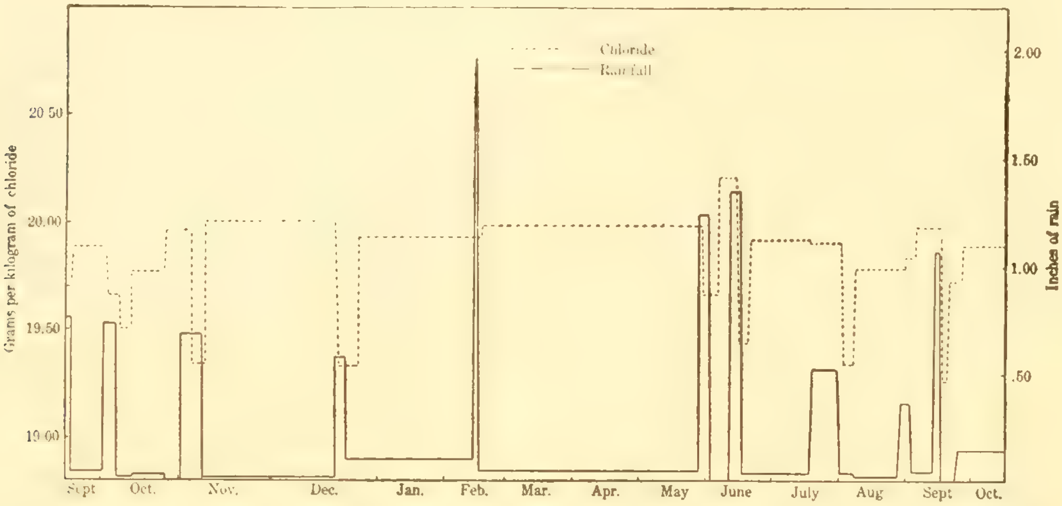


FIG. 6.—Graph showing content of chloride of sea-water at Fowey Rocks and precipitation at Miami, Florida, by selected periods during 1914.

Relation of precipitation at Miami to content of chloride in sea-water at Fowey Rocks.

Period, 1914–15.	Average daily precipitation.	Average chloride content.	Period, 1914–15.	Average daily precipitation.	Average chloride content.
	inches.	*gms. per kg.*		*inches.*	*gms. per kg.*
Sept. 12–13	0.76	19.70	June 1– 7	....	19.70
14–29	.04	.....	4–12	0.00	.....
14–Oct. 1	....	19.89	8–16	....	20.00
30–Oct. 5	.73	.....	13–17	1.34	.....
Oct. 2– 7	....	19.66	17–21	....	19.43
6–12	.01	.....	18–July 19	.03	.....
8–12	....	19.50	22–July 19	....	19.91
13–27	.20	19.77	July 20–Aug. 1	.51	.....
28–Nov. 4	Trace.	.....	20–Aug. 3	....	19.90
28–Nov. 9	....	19.96	Aug. 2– 8	.03	.....
Nov 5–14	.68	.....	4– 8	....	19.34
10–15	....	19.34	9–29	.01	.....
15–Dec. 13	.01	.....	9–Sept. 1	....	19.78
16–Dec. 15	....	20.00	30–Sept. 3	.46	.....
Dec. 14–18	.57	.....	Sept. 2– 6	....	19.83
16–24	....	19.33	4–14	.04	.....
19–Feb. 15	.10	.....	7–17	....	19.79
25–Feb. 17	....	19.93	15–16	1.06	.....
Feb. 16	1.96	.....	18–20	....	19.26
18–19	....	19.94	17–24	Trace.	.....
17–May 28	.04	.....	21–27	....	19.72
20–May 31	....	19.98	25–Oct. 17	.14	.....
May 29–June 3	1.23	.....	28–Oct. 17	....	19.89

If this explanation is correct the normal content of chloride of sea-water off Fowey Rocks is more nearly represented by the average of the determinations that do not fall abnormally below a certain minimum. To obtain this normal content the two very high estimates and the 57 estimates that fall below 19.72 have been omitted; the average of the remaining 329 estimates is 19.93 grams per kilogram of chloride. This corresponds to a salinity of 36.00 grams per kilogram and a specific gravity $\left(\frac{0^\circ}{4^\circ}\right)$ of 1.02894. The average content of chloride of sea-water in the Gulf of Mexico, according to the average of 52 determinations on consecutive daily samples collected in June 1913, from Southwest Channel, Tortugas, is 19.93.[1] Consequently it may be concluded that the normal salinity of the Gulf Stream off Fowey Rocks is like that of the Gulf of Mexico, but that it is decreased at times by rains and by discharge of fresh water from Miami River and underground aquifers along the coast.

COMPARISON WITH SALINITY AT OTHER PLACES.

The accompanying table giving the chloride content and salinity of sea-water at other places on or near the coast of Florida, furnishes data for comparison with the concentration at Fowey Rocks. The range in concentration of samples collected June 23, 1913, from various places in and outside Biscayne Bay shows the effect of fresh water from Miami River and other less abundant sources. The salinities of the samples taken outside the reefs on that date agree closely with each other and with the salinity of gulf water at Tortugas (36.01). The water in the south part of the bay is somewhat more concentrated, three samples having salinities of 36.73, 36.64, and 36.64, respectively. This evidence that the water in this part of the bay is concentrated by evaporation during its retention in the shallows serves further to indicate that circulation there is not very rapid and that the greater bulk of the water inside the keys is not thoroughly mixed or shifted by the tides. The inside samples only as far south as Old Man Beacon give evidence of dilution by fresh water; therefore it may be concluded that, at the time these samples were collected, the effect of Miami River on the water of the bay did not extend south of Soldier Key nor outside the keys. Yet the longer series later examined at Fowey Rocks shows that the diluting effect is at times apparent as far out as the lighthouse. The sample taken off the mouth of Miami River, June 23, 1913, has a salinity obviously higher than the pure water of the river alone may be expected to have and represents admixture with bay-water. Similar diluting effect is shown by the two samples collected September 6, 1914, at different distances from the mouth of Miami River, after a rainfall of 2½ inches in 2 hours.

The average chloride content of 22 samples of sea-water collected on a voyage from Cape of Good Hope to England and analyzed by C. J. S.

[1]See table, p. 302.

Makin[1] is given as 20.6569 grams per liter and the specific gravity at 15.5° C. is given as 1.0275. According to Knudsen's tables this content of chloride, with correction for specific gravity, is approximately equivalent to 19.97 grams per kilogram of chloride, salinity 36.08 grams per kilogram, and a specific gravity $\left(\frac{0^\circ}{4^\circ}\right)$ of 1.0290. The slight difference between this result and the corrected average of results at Fowey Rocks might reasonably be attributed to difference in procedure and in calibration of instruments. The chloride content of standard sea-water sample $P_7{}^2/_2$, 1912, is 19.386 grams per kilogram and the corresponding salinity is 35.02.

The chloride content of the 7 most strongly concentrated bottom samples collected by Mr. E. W. Shaw off the mouth of Mississippi River ranged from 19.81 to 19.99 grams and averaged 19.88 grams per kilogram.[2] This average corresponds to a salinity of 35.91 grams per kilogram.

The salinity of a sample collected by Dr. T. W. Vaughan off the west side of Andros Island in the Bahamas is definitely higher than the salinity in general in Atlantic Ocean, and it is also higher than that on the east side of the Island. The submarine flat off the west side of South Bight is more than 60 miles wide[3] and the maximum depth within this distance is $3\frac{1}{2}$ fathoms. It is therefore not surprising that the salinity should be somewhat higher there by reason of excessive evaporation as compared with that on the east side, where the submarine shore flat is only about 4,500 feet wide, beyond which there is a steep drop to 1,000 fathoms.

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[1]Makin, C. J. S., On the composition of the Atlantic Ocean: Chem. News, vol. 77, pp. 155, 171, 1898; quoted by F. W. Clarke, The data of geochemistry: U. S. Geol. Survey Bull. 616, p. 123, 1916.

[2]Shaw, E. W., The mud lumps at the mouths of the Mississippi: U. S. Geol. Survey Professional Paper 85-b, pp. 11-27, 1914.

[3]Personal communication from Dr. Vaughan. (See discussion by him on page 274 of this volume.)

Chloride content and salinity of sea-water in the vicinity of the coast of Florida.

Source.	Date.	Chloride.	Salinity.
		grams per kilogram.	*grams per kilogram.*
Tortugas, Florida:			
Off Loggerhead Key[1]	1910	19.60	35.41
Reef, Loggerhead Key[2]	June 1912	19.95	36.04
Southwest channel[3]	May and June 1913	19.93	36.01
Southwest channel[2]	June 1912	19.99	36.11
Southwest channel	June 27, 1914	20.02	36.17
Wharf, Fort Jefferson[2]	June 1912	19.99	36.11
Off Garden Key	May 25, 1913	19.84	35.84
Off Garden Key	June 14, 1913	19.96	36.06
Moat, Fort Jefferson[2]	June 1912	20.09	36.29
Moat, Fort Jefferson	Jan. 27, 1913[4]	19.61	35.43
Moat, Fort Jefferson	Jan. 27, 1913[5]	19.60	35.41
Moat, Fort Jefferson	Feb. 27, 1913[4]	19.83	35.82
Moat, Fort Jefferson	Feb. 27, 1913[5]	17.79	32.14
Moat, Fort Jefferson	May 25, 1913	19.67	35.53
Moat, Fort Jefferson	June 14, 1913	19.83	35.82
Moat, Fort Jefferson	June 15, 1913	19.19	34.67
Around Biscayne Bay, Florida:			
Mouth Miami River inside bar near Royal Palm Dock	$4^h 30^m$ a. m., June 23, 1913	1.42	2.59
1.5 miles east of Miami at 11 feet depth in government channel north of Virginia Key.	2 p. m., June 23, 1913	14.73	26.62
Off Cormorant Point (tide ebbing)	$4^h 45^m$ a. m., June 23, 1913	13.35	24.13
1 mile west of west point of Key Biscayne near inside P and O marker.	$5^h 30^m$ a. m., June 23, 1913	16.80	30.35
0.25 mile west of Old Man Beacon	6 a. m., June 23, 1913	18.79	33.95
3 miles northeast of Black Ledge	7 a. m., June 23, 1913	20.33	36.73
0.5 mile west of Soldier Key	9 a. m., June 23, 1913	20.28	36.64
In channel through Featherbed Bank	8 a. m., June 23, 1913	20.28	36.64
1.5 miles west of Fowey Rocks Light, outside bay	11 a. m., June 23, 1913	19.93	36.00
In channel south of Key Biscayne and 0.5 mile south of Old Florida Cape Light, outside bay.	$11^h 45^m$ a. m., June 23, 1913	19.83	35.82
At red buoy outside bar across entrance to Bear Cut, a mile southeast of Virginia Key, outside bay.	$1^h 15^m$ p. m., June 23, 1913	19.99	36.11
Near black buoy 7, in Biscayne Bay	2 p. m., Sept. 6, 1914	15.45	27.92
Near red buoy 4, inside Key Biscayne	2 p. m., Sept. 6, 1914	17.30	31.26
Off Fowey Rocks[6]	Sept. 12, 1914, to Oct. 17, 1915	19.93	36.00
Andros Island:			
West side of island, 2 miles west of the west end of South Bight.	May 14, 1914	21.51	38.86
East side of island, off Cocoanut Point	May 30, 1914	20.15	36.40
East side of island, bottom sample, off Cocoanut Point	May 29, 1914	20.26	36.60

[1]Computed from report of analysis by G. Steiger, U. S. Geological Survey Laboratory, published in The Data of Geochemistry, by F. W. Clarke, U. S. Geol. Survey Bull. 491, p. 113, 1911.
[2]Tested by D. J. Matthews at the Plymouth (England) Laboratory.
[3]Average of tests of daily samples on ebb and flood tide, May 20 to June 16, 1913.
[4]During rain. [5]After rain. [6]Corrected average of 388 tests of daily samples.

THE SOLUBILITY OF CALCITE IN SEA-WATER IN CONTACT WITH THE ATMOSPHERE, AND ITS VARIATION WITH TEMPERATURE.

By Roger C. Wells,
Physical Chemist, U. S. Geological Survey.

The gist of the present paper is that certain equilibria, whose attainment would be expected from laboratory experiments, do not seem to be fully attained under natural conditions in the ocean. The equilibria referred to involve the effect of temperature on the exchange of carbon dioxide between sea-water and the atmosphere and the precipitation or solution, as the case may be, of various solid constituents from or into sea-water. Apparently, the adjustments occur so slowly and the bulk of the ocean is so great, with reference to the surface exposed to the atmosphere, that the expected variations with temperature do not appear in the water of the open ocean.

In a previous paper[1] it has been shown that the solubility of calcite in water in contact with the atmosphere is a function of the temperature. Further determinations seemed desirable for sea-water and have now been made, using a portion of the water collected at Fowey Rocks Light, outside Biscayne Bay, on the east coast of Florida, July 19–25, 1915. The composite of daily samples showed, on analysis by A. A. Chambers, 19.93 parts per thousand of chlorine. It is a pleasure to thank Mr. R. B. Dole for his kindness in contributing this definite sample of sea-water.

Table 1.—*Calcite added to sea-water at 1° C. and air passed daily.*

Interval.	Carbonates per liter.
	Normality.
Start	0.00247
10 days	.00246
12 days	.00241
14 days	.00238
33 days	.00239
40 days	.00236

The method of experimentation was exactly similar to that described in the previous paper. The water, in contact with an excess of calcite, was agitated by a current of outdoor air for long intervals at different temperatures and the dissolved carbonates determined by titration with 0.02 normal $NaHSO_4$, using methyl orange as indicator.

The results obtained are shown in tables 1 and 2. They are stated as "carbonates per liter" and, on account of the uncertainty of the base, in terms of equivalents, one equivalent per liter constituting the usual normal solution.

[1]Jour. Wash. Acad. Sci., vol. 5, 617 (1915).

Incidentally to the titrations, direct determinations of the total carbon dioxide in the cold and warm solutions were made at the conclusions of the runs, giving 0.101 gm. and 0.078 gm. of CO_2 per liter in the cold and warm solutions, respectively.

The results obtained show that under otherwise similar conditions there is a tendency for the colder sea-water to retain more carbonate in solution than the warmer sea-water. What was not expected, however, is the fact that the colder water did not dissolve fresh calcite, but appears rather to have remained almost unchanged during the 40 days' run. In other words, ordinary sea-water appears to contain so much carbonate that in contact with the atmosphere at 1° C. it neither has nor acquires an appreciable solvent action on calcite. At higher temperatures it undergoes a slow diminution in its content of carbonates on being agitated in contact with outdoor air.

TABLE 2.—*Calcite added to sea-water at room temperature and air passed daily.*

Interval.	Temperature.	Carbonates per liter.
	° C.	*Normality*
Start.............	....	0.00247
10 days....	25	.00225
12 days....	25	.00221
14 days..........	26	.00215
33 days..........	28	.00199
35 days..........	29	.00208
40 days...... ...	28	.00196

To compare with the above determinations, I had, fortunately, been able to make a few titrations at sea. At two points in the Caribbean, about 13° N., 81° W., the normality of the carbonates was found to be 0.00236 and 0.00238 at 25° C. Water from the Pacific off Payta, Peru, at 24° C., gave 0.00226. These values are a little higher than those found in the laboratory after a few days' agitation and suggest a condition of saturation, if not supersaturation, with respect to atmospheric conditions. They throw no light on the variations with temperature, however.

TABLE 3.—*Dittmar's results for surface waters.*[1]

Challenger No.	Station No.	Temperature.	Carbonates
		° C.	*Normality.*
384	153	− 1.4	0.00256
1471	318	+14.2	.00235
2	1	18.1	.00286
9	5	20.0	.00260
265	130	20.6	.00260
Dec. 19	143	22.8	.00253
201	97	25.6	.00241

[1]*Challenger* Reports, vol. 1, p. 135. Dittmar showed that deep waters have a slightly higher alkalinity than surface waters, p. 206.

Dittmar made determinations of the "alkalinity," *i. e.*, carbonates, in 130 samples of water collected on the *Challenger*. For reference I have recalculated and give in table 3 results for surface waters only.

It is difficult to see much, if any, regularity, with regard to temperature, in Dittmar's results. There is a slight indication that the "alkalinity" decreases with rising temperature, but the results are too few to show the relation with certainty. Nearly all the values appear to be high. The samples had stood in glass, with occasional exposure to laboratory air, for long intervals, so that one can not help feeling that it would have been better if the titrations had been made on shipboard.

Further determinations were made in the North Sea by E. Ruppin on the *Poseidon*.[1] Some of his results are shown in table 4.

TABLE 4.—*Ruppin's results for water of the North Sea, depth 5 meters.*

Date.	Temperature	Carbonates
	°C.	*Normality.*
Feb. 18, 1907	4.5	0.00234
May 6, 1907	6.0	.00234
May 10, 1907	6.2	.00234
May 8, 1907	6.4	.00238
May 5, 1907	6.7	.00236
May 12, 1906	7.5	.00240
May 19, 1906	9.1	.00240
Nov. 14, 1906	9.3	.00237
Nov. 14, 1906	9.4	.00237
May 11, 1906	9.4	.00240
May 14, 1906	9.5	.00237
Nov. 14, 1906	11.4	.00238
Nov. 13, 1906	12.4	.00239
Aug. 17, 1906	15.1	.00231
Aug. 17, 1906	15.3	.00235
Aug. 15, 1906	15.9	.00238
Aug. 15, 1906	16.2	.00233

In Ruppin's results, also, no relation between the carbonate content and the temperature can be discovered. Nor do any other data on the open ocean known to me bring out the relationship. The inevitable conclusion from the evidence is that the ocean does not come into equilibrium with the atmosphere fast enough to attain the expected adjustment. But further determinations in the colder parts of the ocean are needed, especially in waters that have remained cold and been exposed to the atmosphere for a long time.

Analyses of some of the warmer and nearly inclosed seas, on the other hand, do show a decrease in the carbonate content. In the Red Sea, for instance, Natterer[2] found low values for the carbonates and the deposition of solid carbonates takes place there. It is evident that it is to such portions of the ocean that one must look for variations of the kind discussed in this paper. Moreover, in future examinations of ocean water, as much attention as possible should be paid to currents in the water and to the "previous history" of the water, for it is evident that such factors may mean as much, or more, than its location or temperature at the moment of collection.

[1] Z. anorg. Chem. *66*, 122 (1910). [2] Monatsh. Chem., 20, 1 (1899).

THE TEMPERATURE OF THE FLORIDA CORAL-REEF TRACT.

By Thomas Wayland Vaughan.

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THE TEMPERATURE OF THE FLORIDA CORAL-REEF TRACT.

INTRODUCTION.

The temperature data herewith presented were assembled primarily for their bearing on the effect temperature exerts on the bathymetric and geographic distribution of coral reefs. The following quotation from an article I have recently published will, I believe, immediately indicate the bearing. In discussing the factors which may determine the lower bathymetric limit of shoal-water corals, it is said:[1]

"Another factor is temperature. Dr. Mayer conducted a series of experiments to ascertain the higher and lower limits of temperature which the common corals around the Tortugas can endure. These indicate that a lowering of the temperature to 13.9° C. would exterminate the principal Florida reef corals, while the most important inner flat corals would survive. He obtained similar results on the corals around Murray Island, Australia.

"Dr. H. F. Moore of the U. S. Bureau of Fisheries has communicated to me temperature records made at lighthouses along the Florida reef. These show that vigorous reefs will endure a temperature as low as 18.15° C., the minimum at Carysfort light between 1879 and 1899; but at Fowey Rocks, where the minimum drops to 15.6° C., although there are some corals, there is no thriving reef. The species found at the north end of the reef line are those which Dr. Mayer's experiments showed capable of withstanding the lowest temperature. The temperature records for the reef line indicate 18.15° C. as the minimum temperature which a reef will survive—this is 1.85° C. lower than the figure given by Dana. It is not probable that a reef could withstand a continuous temperature so low as this. Wherever the depth of water is great enough to lower the bottom temperature below 18.15° C., more probably about 21° C., reef corals will not live. This temperature appears to be attained around the Hawaiian Islands within a depth of 183 meters. According to Agassiz's 'Three Cruises of the *Blake*' the bottom temperature in the Gulf of Mexico and the Caribbean Sea is usually too low for the growth of reef corals at a depth of 183 meters, and in places it is too low at a depth of 87 meters. Although the possibility of control of the lower bathymetric limit of reef-building corals by decrease in temperature with increasing depth has not been adequately investigated, it appears safe to say that reef corals are usually, if not always, confined by temperature to water less than 180 meters deep."

The table of salinity and temperature near Bermuda, the Bahamas, and Florida, pages 337, 339, shows that the temperature at 300 meters is uniformly too low for the life of reef corals; it is usually too low at 200 meters; and occasionally too low at 100 meters, in an area where the surface temperature is high enough for the life of reef-forming corals.

Temperature, of course, is not merely a factor in determining bathymetric distribution; it is also one of the most impotrant factors in determining the geographic distribution of sea-level and near sea-level reefs. The importance of this relation is made sufficiently clear in the foregoing quotation.

Dr. Mayer, on page 34 of his paper on the ecology of the Murray Island reef, presents the results of his experiments on the limits of artificial heating

[1] Nat. Acad. Sci. Proc., vol. 2, pp. 97 98, 1916.

and cooling endured by corals. The actual reef records show that reef corals in nature do not withstand so much cooling as in the laboratory experiments. The data at hand indicate that a well-developed fossil reef was not subjected to an annual minimum below 18° C., and that the temperature was so low at only rare intervals. The mean temperature for the coldest months must have been not lower than about 21° C. (about 70° F.), as it seems that a continuous bottom temperature of about 21° C. is the lowest at which reef-forming corals may be expected to live.

One of the needs in the further investigation of corals is more accurate information on bottom temperature between 50 and 300 meters in coral-reef areas. The data here presented are interesting and important, as they constitute a beginning in the accumulation of such data.

The information contained in the following tables has an important bearing on many oceanographic problems, among which is the capacity of the water to hold $CaCO_3$ in solution. This subject is discussed in preceding papers, pages 267–268, 278, 287, 288, 315–317 of this volume.

It is needless to say that this large body of information was only assembled by me. I heartily thank all who have so generously assisted in making it available for this paper.

Summary of climatic data on southern Florida.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Mean temperature (°C.):													
Miami	18.3	19.4	21.7	21.7	24.4	27.2	27.8	27.8	27.2	25.6	23.3	20.6	23.9
Key West	21.6	21.7	22.8	24.4	26.1	27.8	28.9	28.9	29.4	26.1	23.3	21.1	25.0
Myers	16.7	18.3	20.0	22.2	25.0	26.7	27.2	27.2	26.7	23.9	21.1	17.8	22.8
Tampa	15.0	16.7	19.4	21.1	24.4	26.7	27.2	27.8	26.7	23.3	19.4	16.1	22.2
Highest temperature (°C.):													
Miami	29.4	31.1	32.2	33.3	35.6	34.4	33.3	34.4	35.0	33.9	31.1	32.8	35.6
Key West	32.2	30.6	31.7	32.8	33.9	37.8	37.8	37.8	36.1	33.3	32.8	30.6	37.8
Myers	31.7	29.4	31.1	32.2	34.4	34.4	34.4	33.9	33.9	31.7	30.6	28.9	34.4
Tampa	27.8	30.0	31.1	32.2	34.4	35.0	35.6	35.0	34.4	33.3	30.6	28.3	35.6
Lowest temperature (°C.):													
Miami	1.7	−1.7	3.9	7.8	11.1	18.3	20.6	15.6	16.7	12.2	3.3	2.8	−1.7
Key West	5.0	6.7	8.9	15.0	17.2	20.6	20.0	20.0	20.6	16.1	10.6	6.7	5.0
Myers	−2.2	−2.2	3.9	7.2	10.0	14.4	19.4	20.6	16.1	8.9	1.7	−4.4	−4.4
Tampa	−2.7	−5.6	0.0	3.3	11.7	17.8	18.3	18.9	12.2	6.7	0.0	−7.2	−7.2
Average precipitation:													
Miami	4.0	2.5	3.1	3.5	4.5	8.2	7.0	5.4	9.1	7.1	2.3	1.6	58.3
Key West	2.0	1.6	1.2	1.2	3.1	4.2	3.7	4.7	7.0	5.4	2.1	1.7	37.9
Myers	2.1	3.1	2.8	2.5	3.2	11.0	8.6	7.6	8.1	3.1	1.1	1.9	55.1
Tampa	2.8	3.5	2.9	2.1	2.4	8.5	8.0	8.4	8.2	2.8	1.7	1.8	53.1
Average number of rainy days:													
Miami	4	3	4	4	5	8	7	7	12	7	2	2	65
Key West	8	7	5	4	8	12	13	13	13	16	13	7	120
Myers	5	5	4	4	7	15	15	14	14	7	4	4	98
Tampa	8	8	7	6	6	16	18	18	16	7	5	8	123

The summary of climatic data on southern Florida as given in the foregoing table was supplied by the U. S. Weather Bureau.

The following weekly air-temperature records and the monthly averages for Tortugas were contributed by Dr. Alfred G. Mayer.

WEEKLY AIR-TEMPERATURE RECORDS AT TORTUGAS.

Recorded upon a Draper's self-recording thermometer. From June 12 to July 26 the temperatures are those in the new laboratory building on Loggerhead Key. From July 26 to Apr. 4 they are those of the upper tier on the east side of the casemates of Fort Jefferson. From May 11 to June 7, 1913, they are those of the new laboratory building on Loggerhead Key, Tortugas.

Date.	High.	Low.	Aver.	Weekly range.
	°C.	°C.	°C.	°C.
1912				
June 12–18	35.0 (on June 14)	26.7	±30.0	8.3
June 21–28	34.4 (on June 22)	26.1	29.4	8.3
June 28–July 4	31.4	27.0	29.4	4.4
July 5–12	33.6	25.6	28.9	8.0
12–19	32.8	27.2	29.4	5.6
19–26	34.4	26.1	29.4	8.3
July 26–Aug. 2	33.3	27.8	30.6	5.5
Aug. 2– 9	31.4	29.2	30.3	2.2
9–16	30.9	28.9	30.0	2.0
16–23	30.6	27.5	29.4	3.1
23–30	30.9	28.3	30.0	2.6
30–Sept. 6	32.0	28.9	30.9	3.1
Sept. 6–13	31.1	27.5	30.0	3.6
13–20	30.9	27.2	28.9	3.7
20–27	30.6	25.0	28.9	5.6
27–Oct. 4	31.7	27.0	29.4	4.7
Oct. 4–11	30.3	27.5	28.9	2.8
11–18	30.0	27.5	28.9	2.5
18–25	29.7	26.7	28.3	3.0
25–Nov. 1	28.3	24.4	26.7	3.9
Nov. 1– 8	27.2	22.0	25.0	5.2
8–15	26.1	23.9	25.0	2.2
15–22	26.1	21.4	23.9	4.7
22–29	24.4	22.0	23.3	2.4
29–Dec. 6	26.7	21.7	24.4	5.0
Dec. 6–13	26.1	22.8	24.4	3.3
13–20	25.9	19.5 (on Dec. 20)	23.3	6.4
20–27	25.6	20.3	23.1	5.3
1913				
Dec. 27–Jan. 3	25.6	18.9 (on Dec. 28)	22.8	6.7
Jan. 3–10	25.0	20.0	23.3	5.0
10–17	26.1	22.0	23.3	4.1
17–24	27.0	20.3	23.3	6.7
24–Feb. 1	25.6	22.8	24.2	2.8
Feb. 1– 7	25.6	23.3	24.4	2.3
7–14	26.1	22.0	23.9	4.1
14–21	25.0	18.6 (on Feb. 17)	22.2	6.4
21–28	24.7	21.7	23.1	3.0
28–Mar. 7	25.6	22.8	24.2	2.8
Mar. 7–14	27.8	22.8	25.0	5.0
14–21	27.2	21.7	24.4	5.5
21–28	27.8	22.5	25.3	5.3
28–Apr. 4	26.7	23.6	25.3	3.1
Apr. 5–May 20	No records.	No records.		
May 11–18	28.6	23.6	25.6	5.0
18–25	31.4	24.2	26.1	7.2
25–June 1	31.4	23.9	27.5	7.5
June 1– 7	31.1	25.3	28.3	5.8

The highest temperature is 35.0° C. on June 14, 1912, the next highest 34.4° C. on June 22. The lowest temperature is 18.6° C. on February 17, 1913; and the next lowest is 18.9° C. on December 28, 1912, thus giving an extreme range of 16.4° C. The greatest weekly range is 8.3° C. between June 21 to 28, 1912, also July 19 to 26, 1912, and the least 2.0° C. between August 9 to 16.

The following appear to be the average and the extreme temperatures for each month:

Monthly average and range in temperature at Tortugas.

Date.	Aver.	High.	Low.	Date.	Aver.	High.	Low.
	°C.	°C.	°C.		°C.	°C.	°C.
June 1912....	29.7	35.0	26.1	Nov. 1912..	29.8	27.2	21.4
July 1912....	29.5	34.4	25.6	Dec. 1912....	23.8	26.1	18.9
Aug. 1912.....	29.8	30.9	27.5	Jan. 1913....	23.4	27.0	20.0
Sept. 1912.....	29.7	32.0	25.0	Feb. 1913.....	23.4	26.1	18.6
Oct. 1912......	28.2	30.3	24.4	Mar. 1913....	24.7	28.3	21.7

There were three well-marked northers, but they did not produce a weekly range of more than 6.7° C. above the lowest in the norther.

The daily water-temperature records for Fort Jefferson were made by Mr. George C. Short, mate, U. S. N., in accordance with an agreement entered into with Dr. Mayer.

The temperature records for means of ten-day periods along the Florida reef tracts were furnished by Dr. H. F. Moore, of the U. S. Bureau of Fisheries.

The salinity and temperature records near Bermuda, the Bahamas, and Florida were compiled by Mr. W. W. Welsh, naturalist of the U. S. Coast and Geodetic Survey steamer *Bache*, Capt. C. C. Yates commanding, and the copy was supplied by the U. S. Bureau of Fisheries through Dr. H. F. Moore.

I heartily thank all who have so generously assisted in assembling the data.

Except the last mentioned, all the records were in the Fahrenheit scale and have been converted into centigrade by Miss R. L. MacGregor. After conversion all figures were checked by two persons acting jointly.

DAILY WATER-TEMPERATURE RECORD AT FORT JEFFERSON, TORTUGAS, FROM JUNE 16, 1911, TO JUNE 16, 1912.

In addition to the data contained in the table on pages 326-330, the following statement by Dr. Mayer is here pertinent:

"The tides on July 22–23 (the spring tide came on July 21) were very low and the water in the moat was, I am told, 32.8° C. and 33.3° C. Your corals were exposed in this heat in an almost flat calm. The air temperature was 34.7° C. and 35.0° C. respectively on the two days. A great many *Siderastrea radians* seem to have been killed in the exposed parts.

"The temperature of tide pools in shallow places on the reef ranged from 33.0° C. to 38.0° C. at 2 p. m. on July 23, at nearly low (or about low) water; and a great many *Diadema*, large numbers of *Octopus*, *Fissurella*, various mollusca and small fishes were killed."

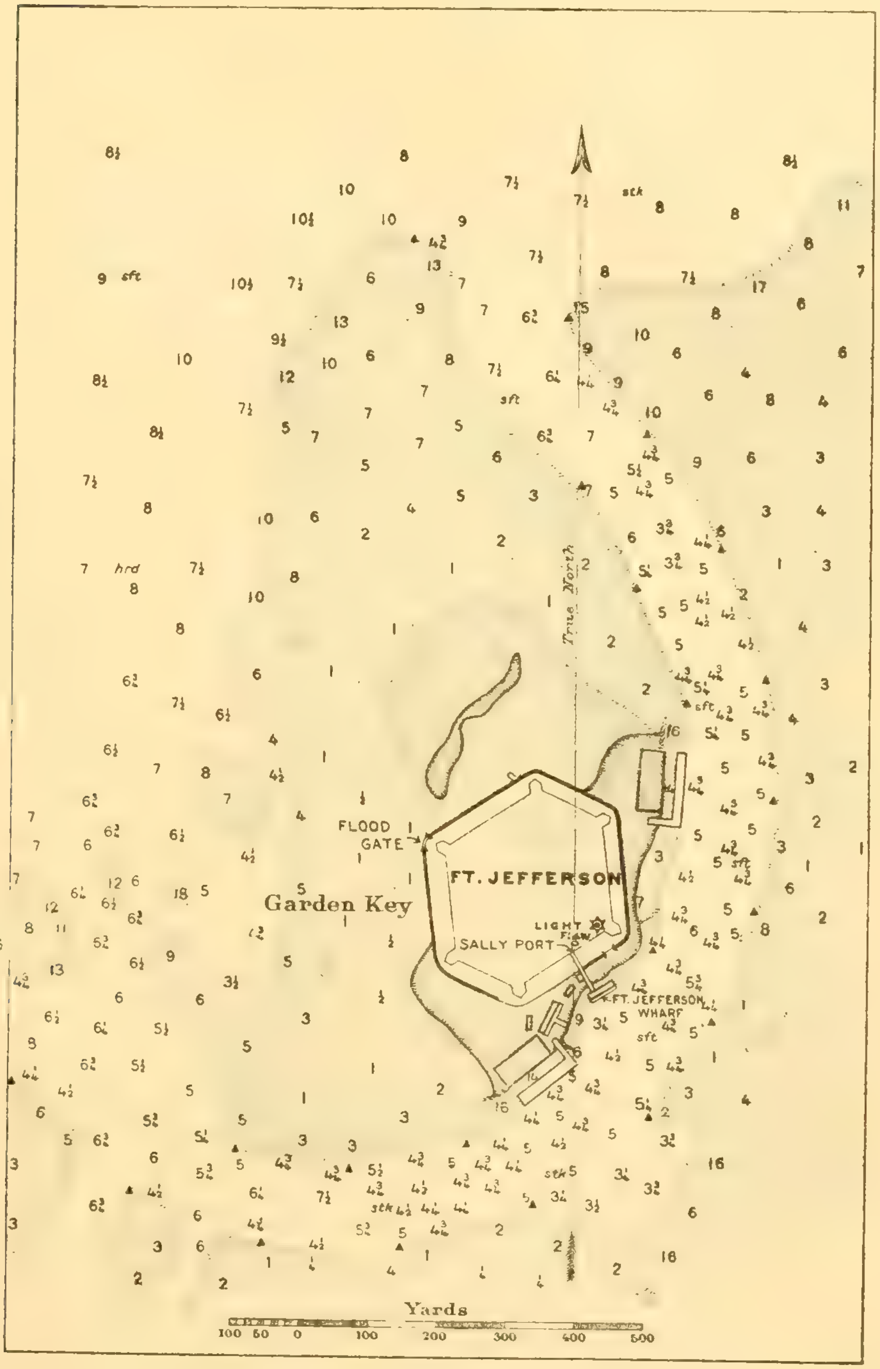

FIG. 7.—Map showing stations at Fort Jefferson, Tortugas, where water-temperature readings were made. Scale $\frac{1}{10000}$.

The accompanying figure (fig. 7) shows the precise location of the stations at which the readings were taken. The coral fauna within the moat and outside the floodgate is that typical for inner flats. The commonest species are *Favia fragum*, *Mæandra areolata*, *M. clivosa*, *Siderastrea radians*, *Porites porites* (= *P. clavaria*), *P. furcata*, and *P. astreoides*. The fauna on the piers of Fort Jefferson wharf, which is next a ship channel, is far more

varied and comprises corals of inner flat, reef, and deeper water facies. Among the species are *Eusmilia fastigiata*, *Oculina diffusa*, *Orbicella annularis*, *Favia fragum*, *Manicina gyrosa*, *Mæandra areolata*, *M. clivosa*, *M. strigosa*, *Mycetophyllia lamarckana*, *Agaricia purpurea*, *Porites porites*, *P. furcata*, *P. astreoides*, and *Millepora alcicornis*. There is more suspended matter in the water of the moat and outside the floodgate when the water has been agitated than under the wharf; and the table shows that the temperature range at the latter two stations is greater than at the former. The inner flat corals are especially resistant to the deleterious effects of sediment, and can survive a wide range of temperature.

Records of temperature of surface water at Fort Jefferson, Tortugas, Florida, from June 16, 1911, to June 16, 1912.

STATIONS AT FORT JEFFERSON.

Date.	Wharf.		Moat (sally-port).		Outside moat at floodgate.		Date.	Wharf.		Moat (sally-port).		Outside moat at floodgate.	
	Temp. 7 a.m.	Temp. 3 p.m.	Temp. 7 a.m.	Temp. 3 p.m.	Temp. 7 a.m.	Temp. 3 p.m.		Temp. 7 a.m.	Temp. 3 p.m.	Temp. 7 a.m.	Temp. 3 p.m.	Temp. 7 a.m.	Temp. 3 p.m.
1911	°C.	°C.	°C.	°C.	°C.	°C.	1911	°C.	°C.	°C.	°C.	°C.	°C.
June 16	28.3	28.9	28.9	30.0	27.8	30.6	July 28	29.4	29.4	29.4	30.0	29.4	30.0
17	28.3	30.6	28.9	31.1	28.9	31.1	29	27.8	30.0	27.8	29.4	28.3	30.6
18	28.3	30.0	28.9	31.1	28.3	31.1	30	28.3	30.6	28.3	30.6	28.3	30.6
19	27.8	29.4	28.3	30.0	28.3	29.4	31	28.9	31.1	28.3	31.7	28.3	31.1
20	27.8	30.0	27.8	30.0	27.8	30.6	Aug. 1	28.9	31.1	29.4	30.6	28.9	31.1
21	28.3	29.4	28.3	30.0	28.3	30.6	2	28.9	31.1	28.3	31.1	28.3	31.7
22	28.3	30.0	28.9	30.6	28.3	31.1	3	29.4	31.1	29.4	31.7	29.4	32.2
23	28.3	30.0	28.9	31.1	27.8	31.1	4	30.0	32.8	30.0	32.2	30.0	32.8
24	28.3	30.6	28.9	31.7	28.3	32.0	5	29.4	31.1	30.0	32.8	29.4	33.1
25	28.9	30.6	28.9	31.1	28.3	31.1	6	30.0	32.2	30.6	33.3	30.0	33.9
26	28.3	30.0	28.9	31.1	28.3	31.1	7	30.0	31.7	30.6	33.3	30.6	33.3
27	27.8	29.4	28.3	30.0	28.3	30.0	8	30.6	29.4	30.6	29.4	30.6	30.0
28	27.8	29.4	27.8	30.6	27.8	30.0	9	29.4	29.4	28.9	28.9	28.9	28.9
29	28.3	30.0	27.8	30.6	27.8	30.6	10	28.3	28.3	27.8	27.8	27.8	28.3
30	27.8	30.6	28.3	31.1	27.8	31.1	11	28.3	30.0	27.8	29.4	27.8	30.0
July 1	28.3	30.9	28.3	31.1	28.3	30.9	12	28.3	30.0	27.8	29.4	27.8	30.0
2	28.3	30.6	28.9	31.1	28.3	30.6	13	28.3	30.0	27.8	29.4	27.8	30.0
3	28.3	29.7	28.9	30.6	28.9	30.0	14	27.8	27.8	28.3	26.7	27.8	27.8
4	28.9	30.0	29.4	31.1	28.9	30.6	15	27.8	29.4	27.2	28.9	26.7	30.0
5	28.9	30.6	29.4	31.1	28.9	30.6	16	27.8	31.1	27.8	30.0	27.2	31.1-
6	28.9	29.4	29.4	30.6	28.9	30.6	17	28.3	31.7	30.0	31.1	27.8	31.7
7	28.9	30.0	28.9	30.6	28.9	30.6	18	28.3	31.7	28.9	31.1	28.3	31.7
8	28.9	30.0	28.9	30.6	28.3	30.0	19	28.3	30.6	28.9	31.1	29.4	30.6
9	28.3	29.4	28.9	30.6	28.3	30.6	20	28.9	30.6	29.4	30.6	29.4	30.6
10	28.3	30.0	28.3	30.6	28.3	30.6	21	30.0	30.6	30.0	32.2	29.4	32.2
11	28.9	30.0	28.9	30.6	28.3	30.6	22	29.4	30.0	29.4	30.6	30.0	30.0
12	28.3	30.6	28.9	30.6	28.3	30.6	23	28.9	30.0	28.9	30.6	28.9	30.6
13	28.3	29.4	28.9	30.0	28.3	29.4	24	28.3	30.6	28.3	30.0	27.8	30.0
14	28.3	30.0	27.8	30.6	28.3	30.6	25	28.9	30.0	28.3	30.0	28.3	30.6
15	28.9	30.0	28.9	30.6	28.9	30.6	26	28.9	30.0	28.9	30.6	28.9	30.6
16	28.9	30.0	28.3	30.6	28.3	30.6	27	28.3	30.0	29.4	30.6	29.4	30.6
17	28.9	30.6	28.3	31.1	28.3	30.6	28	28.9	30.6	29.4	31.1	29.4	31.1
18	28.9	31.1	28.9	31.1	28.3	31.1	29	28.9	30.0	29.4	31.3	28.9	30.6
19	28.3	31.1	28.9	31.7	28.9	31.1	30	28.3	30.0	28.3	30.6	28.9	30.6
20	28.9	30.6	29.4	31.7	28.9	31.1	31	28.9	30.6	29.2	31.1	28.9	31.1
21	28.9	31.1	29.4	32.2	29.4	32.2	Sept. 1	28.3	31.1	28.9	31.1	28.9	31.1
22	29.4	32.2	30.6	32.8	30.0	32.8	2	28.9	29.4	28.9	30.0	28.9	30.0
23	30.0	32.2	30.6	32.8	30.0	33.3	3	28.9	30.0	28.3	30.6	28.3	30.6
24	30.0	32.2	30.0	32.8	29.4	32.8	4	28.9	30.0	28.9	31.1	28.9	31.1
25	29.4	32.2	30.0	32.8	29.4	32.2	5	28.9	31.7	29.4	31.7	28.9	31.7
26	29.4	30.6	30.0	31.7	29.4	31.1	6	29.4	31.1	29.4	31.1	29.4	31.1
27	29.4	30.0	29.4	31.7	29.4	30.6	7	28.9	30.6	28.3	30.0	28.3	30.6

Records of temperature of surface water at Fort Jefferson, Tortugas, Florida, from June 16, 1911, to June 16, 1912—Continued.

STATIONS AT FORT JEFFERSON—Continued.

Date.	Wharf.		Moat (sally-port).		Outside moat at floodgate.	
	Temp. 7 a.m.	Temp. 3 p.m.	Temp. 7 a.m.	Temp. 3 p.m.	Temp. 7 a.m.	Temp. 3 p.m.
1911	°C.	°C.	°C.	°C.	°C.	°C.
Sept. 8	28.9	30.6	28.3	30.6	28.9	30.6
9	28.9	30.6	28.3	31.1	28.3	21.1
10	28.3	29.4	27.8	29.4	27.8	29.4
11	28.9	30.0	28.3	30.6	28.3	30.6
12	28.9	30.6	28.9	31.1	28.9	31.1
13	28.3	30.6	28.9	31.7	28.9	31.1
14	28.9	31.1	28.9	31.1	28.9	31.1
15	28.9	30.0	28.3	30.6	28.9	30.6
16	27.8	29.4	26.7	30.0	27.2	30.0
17	27.8	29.4	27.2	30.0	27.2	30.0
18	28.3	28.9	27.2	30.6	27.8	30.0
19	28.3	30.0	28.9	30.6	28.3	30.6
20	28.9	29.4	28.9	30.6	28.9	30.6
21	28.9	30.0	28.3	31.1	28.9	30.9
22	28.6	30.6	28.3	31.1	28.3	31.1
23	28.9	30.6	28.3	30.0	28.3	30.6
24	28.9	29.4	28.3	30.0	28.9	29.4
25	28.3	28.9	27.8	28.9	28.3	28.9
26	28.3	28.3	27.2	27.8	28.3	28.3
27	28.3	28.3	27.2	27.2	27.8	27.8
28	27.8	27.8	26.7	27.8	27.2	28.3
29	28.3	28.3	27.2	27.8	27.8	27.8
30	28.3	27.8	27.8	28.3	27.8	28.3
Oct. 1	28.3	29.4	27.8	29.4	27.2	29.4
2	27.8	30.0	27.2	30.6	27.8	30.0
3	28.3	29.4	27.8	30.0	28.3	30.6
4	27.8	28.9	27.2	29.7	27.8	30.0
5	28.3	29.4	27.8	30.0	27.8	30.0
6	28.3	29.4	28.1	30.6	28.3	30.6
7	27.8	29.4	28.3	30.0	28.3	30.0
8	28.3	30.0	27.8	30.6	27.8	30.6
9	28.3	30.0	28.3	30.0	28.3	30.0
10	28.3	29.4	27.8	31.0	27.8	30.0
11	28.9	30.0	27.8	30.0	27.8	30.3
12	28.9	30.3	28.3	30.6	28.3	30.6
13	28.9	30.6	28.3	30.6	28.3	31.1
14	28.9	30.0	28.3	30.6	28.3	30.6
15	28.9	29.4	28.3	30.0	28.9	30.6
16	28.9	29.4	28.9	30.0	28.3	30.0
17	28.9	29.4	28.3	29.4	27.8	29.4
18	28.3	28.9	27.8	29.4	27.8	29.4
19	27.8	29.4	27.2	28.9	27.8	30.0
20	27.2	28.9	27.2	29.4	27.8	30.0
21	27.8	28.9	27.8	28.9	27.8	30.0
22	27.8	28.9	27.2	29.4	27.2	29.4
23	27.8	28.9	27.2	29.4	27.8	29.4
24	27.2	28.9	27.8	29.4	28.3	29.4
25	27.8	28.9	28.3	28.9	27.8	28.9
26	27.8	28.9	27.5	28.9	27.5	28.9
27	27.2	28.3	27.8	28.3	27.8	28.3
28	27.2	28.3	26.7	27.8	27.5	28.3
29	27.2	28.3	26.7	27.8	26.7	27.8
30	27.2	28.3	27.2	27.2	26.7	27.8
31	26.7	28.1	27.2	27.2	27.2	27.2
Nov. 1	26.7	27.8	26.7	27.2	26.7	26.7
2	26.7	27.8	27.2	27.8	27.2	27.2
3	27.2	27.8	26.7	27.2	27.2	27.2
4	27.2	28.3	26.7	27.8	26.9	28.3
1911	°C.	°C.	°C.	°C.	°C.	°C.
Nov. 5	27.2	27.8	27.2	27.8	26.7	27.8
6	26.7	28.3	27.2	28.3	26.7	28.3
7	27.2	27.8	26.7	27.8	27.2	28.3
8	27.2	28.3	26.7	28.3	27.2	28.3
9	27.8	28.3	26.7	28.9	26.7	28.3
10	27.2	28.3	26.7	28.9	26.7	28.3
11	26.7	28.3	26.7	28.9	26.7	27.8
12	26.7	27.8	27.2	28.3	26.7	28.3
13	26.7	27.2	26.7	27.8	26.7	26.7
14	26.7	27.8	26.1	27.8	26.7	27.8
15	26.7	28.3	26.1	28.3	26.1	28.3
16	27.2	28.9	26.7	28.3	26.7	28.9
17	27.2	28.3	26.7	27.8	26.7	28.3
18	26.7	27.2	26.1	26.7	25.6	30.0
19	25.6	25.6	25.6	26.1	25.6	26.7
20	25.0	24.4	24.4	23.9	23.9	23.9
21	25.6	24.4	23.3	25.0	23.9	24.4
22	24.4	25.6	22.2	23.3	23.3	24.4
23	24.4	25.6	22.2	24.4	24.4	25.6
24	25.0	25.6	24.4	25.6	24.4	26.1
25	24.4	24.4	23.3	24.4	23.9	24.4
26	24.4	24.4	22.2	23.3	23.3	23.9
27	24.4	24.4	22.2	24.4	22.2	24.4
28	24.4	25.6	23.3	24.4	23.3	25.6
29	24.4	23.3	24.4	23.3	24.4	24.4
30	23.3	22.2	25.6	20.0	22.2	22.2
Dec. 1	22.2	22.2	17.8	18.9	21.1	22.2
2	21.1	22.2	18.9	20.0	21.1	22.3
3	21.7	21.1	20.0	20.0	21.1	22.2
4	21.1	21.1	20.0	20.6	21.1	20.6
5	20.0	22.2	18.9	20.0	22.2	22.2
6	21.1	22.2	20.0	20.0	20.0	21.7
7	21.1	22.2	20.0	20.0	20.6	21.1
8	21.1	22.2	19.4	22.2	20.0	21.7
9	21.1	22.2	20.0	22.2	20.6	22.2
10	21.1	22.2	20.0	21.1	20.0	22.2
11	20.6	22.2	20.0	22.2	20.0	22.2
12	21.1	22.2	21.1	22.2	20.0	22.2
13	21.7	22.2	21.7	22.2	21.7	22.2
14	21.7	22.8	21.7	22.2	22.2	23.3
15	22.2	23.3	22.2	23.3	21.7	23.9
16	22.8	23.9	22.8	23.9	22.2	23.9
17	23.3	23.9	22.8	24.4	22.8	24.4
18	22.8	22.8	22.8	23.3	22.2	22.8
19	22.2	22.8	22.2	23.3	22.2	23.3
20	22.2	23.9	22.2	23.3	22.8	23.9
21	23.3	24.4	22.8	24.4	23.3	24.4
22	23.3	23.9	23.3	24.4	23.3	24.4
23	23.3	24.4	23.3	25.0	23.3	25.0
24	23.3	24.4	24.4	25.6	23.9	25.0
25	23.9	24.4	24.4	25.0	24.4	24.4
26	23.3	25.0	23.3	24.4	23.9	25.0
27	23.3	24.4	23.3	25.0	23.9	24.4
28	21.7	22.2	21.1	21.7	21.7	22.2
29	21.1	22.8	18.9	22.2	20.6	22.2
30	21.1	22.8	20.0	22.2	21.1	22.2
31	21.1	22.8	21.7	23.3	21.7	23.9

Records of temperature of surface water and of the air at Fort Jefferson, Tortugas, Florida, from June 16, 1911, to June 16, 1912—Continued.

STATIONS AT FORT JEFFERSON—Continued.

Date.	Wharf.						Moat (sally-port).						Outside moat at floodgate.					
	A. M.	Temp.		P. M.	Temp.		A. M.	Temp.		P. M.	Temp.		A. M.	Temp.		P. M.	Temp.	
		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.
1912	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*
Jan. 1	6 55	22.8	23.3	3 15	23.9	21.7	7	22.8	23.3	3 18	24.4	23.9	7 05	22.2	23.3	3 23	23.9	23.9
2	7 02	22.2	22.2	3 08	23.3	21.1	7 05	22.2	21.7	3 11	23.9	23.3	7 10	22.2	21.1	3 16	23.3	23.3
3	7	22.2	21.1	3 05	23.9	21.1	7 06	23.3	23.3	3 08	24.4	25.0	7 10	22.2	23.3	3 14	23.9	25.0
4	7 02	23.3	21.7	3 07	23.3	20.6	7 04	23.3	23.3	3 10	24.4	21.1	7 09	23.3	23.3	3 15	23.3	21.1
5	7 01	22.2	21.1	3	23.9	20.6	7 05	22.2	22.8	3 04	23.3	21.7	7 11	22.2	21.1	3 09	23.3	23.3
6	7	21.1	20.6	3 05	22.8	21.1	7 03	21.7	15.0	3 08	23.3	19.4	7 08	21.1	20.6	3 13	22.2	21.1
7	6 59	19.4	20.6	3	20.0	21.1	7 03	17.2	21.1	3 04	18.3	23.3	7 05	19.4	21.1	3 09	19.4	23.3
8	6 55	22.2	22.2	2 59	23.3	23.9	6 59	21.1	23.3	3 02	22.2	23.9	7 03	22.2	22.2	3 08	22.8	23.9
9	6 53	22.8	23.3	3 07	21.7	18.9	6 57	22.2	17.2	3 13	21.1	18.9	7 03	22.2	23.3	3 18	21.7	24.4
10	6 49	20.0	17.2	3 05	20.0	17.8	6 54	17.8	22.2	3 09	18.9	17.8	7 04	20.0	17.2	3 14	19.4	17.8
11	6 55	21.7	22.2	2 58	22.2	23.3	6 58	21.7	22.2	3 03	22.2	23.3	7 09	21.1	22.2	3 08	22.2	23.3
12	7 01	22.2	21.7	2 59	23.3	18.9	7 04	21.7	21.7	3 04	23.3	23.3	7 14	22.2	22.2	3 10	23.3	23.3
13	7 05	23.3	16.7	3 07	23.3	16.7	7 09	23.3	16.7	3 13	22.8	18.9	7 15	23.3	21.7	3 18	23.3	20.6
14	7 10	22.2	17.2	3 04	22.2	20.0	7 14	21.1	17.2	3 10	21.1	16.7	7 19	22.2	16.7	3 15	22.8	16.7
15	7 03	22.8	17.2	3	23.9	14.4	7 08	21.7	17.2	3 05	21.1	20.0	7 14	22.8	17.2	3 11	22.2	20.0
16	7	21.7	17.2	3 05	21.1	14.4	7 04	21.1	16.1	3 10	20.6	19.4	7 09	21.7	17.2	3 15	21.7	14.4
17	7 04	21.1	16.1	3	22.2	20.0	7 09	20.0	17.8	3 06	21.1	20.0	7 14	21.1	16.1	3 12	22.2	20.0
18	7	22.8	20.6	3 04	24.4	22.2	7 05	21.7	22.2	3 09	22.8	22.2	7 10	22.2	17.8	3 15	23.3	22.2
19	6 55	23.3	22.2	3 10	23.9	24.4	6 59	22.2	20.6	3 15	24.4	24.4	7 05	22.8	22.2	3 20	23.9	24.4
20	6 53	22.8	20.6	3 07	23.9	21.7	6 55	21.7	20.0	3 13	23.3	21.7	7 01	22.2	20.6	3 19	24.4	21.7
21	7 02	21.1	20.0	3 02	22.2	20.6	7 00	20.0	19.4	3 08	21.1	20.6	7 11	21.1	20.0	3 13	22.2	20.6
22	7 08	20.6	19.4	3 05	24.4	21.7	7 03	19.4	20.0	3 10	21.7	21.7	7 09	20.6	19.4	3 15	23.9	21.7
23	7 07	23.3	17.8	3 01	23.3	21.1	7 10	22.8	20.6	3 09	23.9	21.1	7 15	23.3	20.6	3 15	23.3	21.1
24	7 02	23.9	19.4	3 03	24.4	22.2	7 17	22.8	21.1	3 08	22.8	22.2	7 23	23.3	19.4	3 14	23.9	22.2
25	6 59	21.7	20.0	3 07	22.2	21.7	7 06	20.0	21.7	3 13	20.6	21.7	7 12	21.1	20.0	3 18	22.2	21.7
26	7 06	22.8	20.6	3 02	23.3	21.1	7 03	21.7	22.2	3 08	22.8	21.1	7 08	22.2	20.6	3 13	23.3	21.1
27	7 04	20.6	21.1	3 05	23.3	22.8	7 10	20.0	22.8	3 11	24.4	22.8	7 15	21.1	21.1	3 16	23.9	22.8
28	7	21.1	21.7	3 11	23.3	23.3	7 08	20.0	17.2	3 16	23.9	23.3	7 14	21.1	21.7	3 20	23.3	23.3
29	7 09	21.7	22.2	3 15	24.4	23.3	7 04	19.4	22.2	3 20	24.4	23.3	7 09	21.7	22.2	3 25	24.4	23.3
30	7 03	23.3	22.8	3 06	23.9	19.4	7 12	23.9	22.8	3 11	23.3	16.7	7 18	23.3	22.8	3 17	23.9	19.4
31	6 55	22.8	17.2	3 03	22.8	17.2	7 06	21.7	20.0	3 08	21.1	17.2	7 11	22.8	17.2	3 13	22.2	17.2
Feb. 1	6 59	21.7	15.6	3 05	22.2	17.2	7 02	21.7	15.6	3 08	22.2	17.2	7 07	22.2	15.6	3 23	22.2	17.2
2	7 01	23.3	16.7	3 10	21.7	17.8	7 04	21.7	16.7	3 13	21.1	17.8	7 09	21.7	16.7	3 16	22.8	17.8
3	7 03	22.2	18.3	3 09	22.2	20.0	7 07	21.1	18.3	3 12	22.8	20.0	7 12	22.2	16.7	3 14	22.2	20.0
4	7 01	22.8	17.8	3	22.8	21.1	7 04	21.7	17.8	3 04	22.2	21.1	7 09	22.2	18.3	3 15	22.2	21.1
5	7 04	22.2	15.6	3 02	21.7	18.9	7 08	21.1	15.6	3 05	21.7	18.9	7 10	21.7	17.8	3 09	21.1	20.0
6	7 01	21.1	14.4	3 06	19.4	16.1	7 04	20.6	12.8	3 05	20.6	16.1	7 10	21.1	15.6	3 14	21.7	16.1
7	7 05	20.0	13.3	3 05	20.6	15.0	7 09	17.8	13.3	3 08	18.9	15.0	7 14	20.6	12.8	3 09	20.0	15.6
8	7	20.0	13.9	3	20.0	16.7	7 03	17.2	13.9	3 03	20.0	16.7	7 09	20.0	13.3	3 08	20.0	16.7
9	6 55	21.1	20.0	3 07	20.6	21.1	6 59	17.8	20.0	3 10	20.6	17.2	7 05	21.1	13.9	3 18	23.3	17.2
10	6 58	21.1	16.7	3 05	21.1	17.2	7 02	20.0	16.7	3 08	19.4	21.1	7 08	21.7	20.0	3 14	21.1	21.1
11	6 55	21.7	15.6	3 08	21.1	18.9	6 58	20.0	15.6	3 12	21.1	18.9	7 03	21.1	16.7	3 09	21.1	18.9
12	7 02	21.1	15.6	3 06	20.6	15.6	7 06	19.4	15.6	3 09	20.6	15.6	7 11	21.1	15.6	3 09	20.6	15.6
13	7 01	21.1	15.6	3 07	21.1	20.0	7 05	20.0	17.8	3 10	21.1	20.0	7 10	21.1	15.6	3 18	21.1	20.0
14	7 04	21.1	20.0	3 02	21.1	21.1	7 07	17.8	18.3	3 06	21.1	21.1	7 13	21.7	20.0	3 16	21.7	21.1
15	7 03	21.1	18.3	3 03	20.6	19.4	7 07	20.6	15.6	3 07	20.0	19.4	7 12	21.7	18.3	3 11	20.6	19.4
16	7	20.0	15.6	3 09	20.6	17.8	7 04	18.9	19.4	3 12	21.1	17.8	7 10	20.0	15.6	3 15	20.6	17.8
17	6 58	20.0	19.4	3 10	21.1	23.3	7 02	20.0	20.0	3 13	27.8	23.3	7 08	20.0	19.4	3 11	21.1	23.3
18	6 55	20.6	20.0	3 15	21.1	21.1	6 59	21.1	17.2	3 18	21.7	21.1	7 05	21.1	20.0	3 15	22.2	21.1
19	7 02	20.0	17.2	3 01	20.6	18.9	7 05	20.6	18.9	3 04	21.7	18.9	7 11	21.1	17.2	3 20	21.7	18.9
20	7 05	20.6	18.9	3 04	21.1	21.1	7 08	20.0	21.1	3 07	23.3	21.1	7 01	20.6	18.9	3 18	21.1	21.1
21	7 01	21.1	21.1	3 06	22.2	24.4	7 05	21.1	21.1	3 10	23.3	24.4	7 12	21.7	21.1	3 13	23.9	24.4
22	7 03	21.7	15.6	3	20.0	14.4	7 07	20.6	15.6	3 03	21.7	20.0	7 08	21.1	15.6	3 16	20.6	20.0
23	7 05	20.0	20.0	3 02	20.6	20.6	7 07	20.6	20.0	3 08	20.0	20.6	7 08	20.6	20.0	3 10	20.0	20.6
24	7	20.6	20.6	3 02	22.2	28.3	7 02	20.0	20.6	3 05	22.8	28.3	7 08	20.0	20.6	3 10	22.8	28.3
25	7 03	20.6	20.0	2 58	22.8	27.8	7 05	21.1	20.0	2 58	23.3	27.8	7 10	21.1	20.0	3 05	21.7	27.8
26	6 58	21.1	21.1	3	23.3	26.1	7 01	22.2	21.1	3 02	23.9	26.1	7 05	21.1	21.1	3 08	23.3	26.1
27	6 50	21.1	21.1	3	22.2	20.6	6 53	19.4	19.4	3 03	23.9	20.6	6 58	22.2	21.1	3 10	22.8	21.1
28	6 55	20.6	20.6	3 05	21.7	17.8	6 58	21.1	17.8	3 08	22.8	17.8	7 05	20.6	16.1	3 13	22.2	17.8

Records of temperature of surface water and of the air at Fort Jefferson, Tortugas, Florida, from June 16, 1911, to June 16, 1912—Continued.

STATIONS AT FORT JEFFERSON—Continued.

Date.	Wharf.						Moat (sally-port).						Outside moat at floodgate.					
	A. M.	Temp.		P. M.	Temp.		A. M.	Temp.		P. M.	Temp.		A. M	Temp.		P. M.	Temp.	
		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.
1912	*h m*	°C.	°C.	*h m*	°C.	°C.	*h m*	°C.	°C.	*h m*	°C.	°C.	*h m*	°C.	°C.	*h m*	°C.	°C.
Feb. 29	7 07	21.1	17.8	3 11	22.8	21.1	7 09	21.7	18.9	3 14	23.3	21.1	7 15	21.1	17.8	3 17	23.3	21.1
Mar. 1	7	21.1	18.9	3	21.7	20.0	7 03	21.7	18.9	3 03	22.8	20.0	7 08	21.1	18.9	3 08	22.8	21.1
2	7 02	21.1	18.9	3 02	22.2	21.7	7 05	21.1	18.9	3 05	23.3	23.3	7 08	21.1	20.0	3 08	22.8	21.1
3	7 04	21.1	20.0	3	23.3	23.3	7 07	21.7	20.0	3 03	23.3	22.2	7 16	21.1	20.0	3 12	23.9	23.3
4	7	21.7	20.0	3	23.9	24.4	7 03	21.1	20.0	3 08	24.4	24.4	7 08	22.2	20.0	3 14	23.9	24.4
5	7	22.2	20.6	3 02	23.3	22.8	7 03	22.2	20.6	3 05	23.9	22.8	7 08	22.2	20.6	3 08	23.9	22.8
6	7 05	23.3	20.0	3	23.3	21.1	7 08	22.8	20.0	3 08	23.9	21.1	7 13	23.3	20.0	3 13	23.3	21.1
7	7	22.8	20.0	3 05	23.9	23.3	7 03	22.2	20.0	3 08	24.4	23.3	7 08	22.8	20.0	3 13	24.4	23.3
8	7 06	22.8	21.1	3 02	24.4	25.6	7 09	22.2	21.1	3 03	25.0	24.4	7 14	22.8	21.1	3 08	25.0	25.6
9	7	23.9	21.1	3 03	24.4	23.3	7 03	23.3	21.1	3 05	25.6	23.3	7 08	23.3	21.1	3 10	25.6	23.3
10	7 02	23.3	19.4	3 06	23.3	18.9	7 05	22.8	19.4	3 09	24.4	24.4	7 10	22.8	19.4	3 14	24.4	20.6
11	7 05	22.8	19.4	3	24.4	23.3	7 06	22.2	19.4	3 03	23.9	23.3	7 13	22.8	19.4	3 08	23.9	23.3
12	7	23.3	22.2	3 05	24.4	25.6	7 03	22.8	22.2	3 08	25.6	25.6	7 08	23.3	22.2	3 13	24.4	25.6
13	7 04	23.9	22.2	3	24.4	23.9	7 08	24.4	22.2	3 03	26.1	23.9	7 13	23.9	22.2	3 08	24.4	23.9
14	7	24.4	21.7	3 03	25.6	24.4	7 03	26.1	21.7	3 06	25.9	24.4	7 08	24.4	21.7	3 11	26.7	24.4
15	7 06	25.0	22.8	3 05	26.1	25.0	7 09	25.6	22.8	3 08	26.7	25.0	7 11	25.6	22.2	3 13	27.2	25.0
16	7	23.3	20.0	3	22.8	21.1	7 02	23.3	20.0	3 03	22.8	21.1	7 07	23.3	20.0	3 08	23.3	21.1
17	7 05	20.0	18.9	3 02	26.7	26.1	7 08	18.3	18.9	3 04	26.7	26.1	7 10	18.3	20.0	3	26.7	26.1
18	7	22.2	21.1	3 03	27.8	23.9	7 03	22.8	21.1	3 08	27.8	23.9	7 08	21.1	21.1	3 10	27.8	23.9
19	6 59	24.4	21.1	3 05	25.6	23.3	7	24.4	21.1	3 06	26.7	23.3	7 06	24.4	21.1	3 13	26.7	23.3
20	7	23.9	22.2	3 02	26.1	24.4	7 03	24.4	22.2	3 06	26.7	24.4	7 10	25.0	22.2	3 11	27.2	24.4
21	7 05	24.4	23.9	3	26.7	25.0	7 03	23.3	23.9	3 03	27.8	25.0	7 12	23.9	23.9	3 08	28.3	25.0
22	7	25.0	23.3	3 05	26.7	26.1	7 03	24.4	23.3	3 08	27.2	26.1	7 10	23.9	23.3	3 13	26.7	26.1
23	7 05	24.4	21.1	3	27.2	24.4	7 08	23.9	21.1	3 05	27.8	24.4	7 12	23.3	21.1	3 10	27.8	24.4
24	6 58	25.6	22.8	3 05	26.7	24.4	7	24.4	22.8	3 08	27.2	24.4	7 08	24.4	22.8	3 13	27.2	24.4
25	7	25.0	23.3	3	24.4	18.9	7 03	25.6	22.2	3 03	23.3	18.9	7 10	25.6	22.2	3 09	22.8	18.9
26	7 05	23.3	19.4	3 04	25.6	25.6	7 08	22.2	19.4	3 08	24.4	21.1	7 13	22.8	19.4	3 14	21.1	22.2
27	7	23.9	18.9	3	25.6	22.2	7 05	23.3	18.9	3 03	24.4	22.2	7 10	23.3	18.9	3 08	25.0	22.2
28	7 08	24.4	21.1	3 08	26.1	23.3	7 11	23.9	21.1	3 11	26.7	23.3	7 16	23.9	21.1	3 16	26.7	23.3
29	7	25.0	22.2	3	26.7	26.1	7 05	24.4	22.2	3 03	27.2	26.1	7 10	24.4	22.2	3 08	26.7	26.1
30	6 58	25.0	23.9	3 05	27.2	27.8	7 04	25.0	23.9	3 08	28.3	28.3	7 09	25.0	23.9	3 13	28.3	28.3
31	7	25.6	24.4	3	26.7	26.1	7	25.0	24.4	3 03	27.2	26.1	7 10	25.6	24.4	3 10	26.7	26.1
Apr. 1	7	25.6	23.3	3 05	27.2	26.1	7 05	26.1	23.3	3 08	28.3	26.1	7 10	25.6	23.3	3 13	29.4	26.1
2	6 57	25.6	22.8	3 08	27.8	28.9	7 02	26.1	22.8	3 01	28.3	26.7	7 07	25.6	22.8	3 16	28.3	26.7
3	7	25.6	23.9	3	26.1	23.9	7 03	26.7	23.9	3 03	27.8	22.8	7 08	27.2	23.9	3 08	27.2	22.8
4	7 02	23.9	22.2	3 05	25.6	23.3	7 06	24.4	22.2	3 08	24.4	23.3	7 10	24.4	22.2	3 13	24.4	23.3
5	6 58	22.3	22.2	3 06	25.0	23.3	7 02	22.8	22.2	3 10	24.4	23.3	7 08	22.2	22.2	3 15	24.4	23.3
6	7	24.4	22.2	3	25.6	22.8	7 03	23.3	22.2	3 14	25.0	22.8	7 09	23.3	22.2	3 10	25.0	22.8
7	7 05	23.9	23.3	3 08	26.1	23.9	7 08	23.3	23.3	3 11	25.6	23.9	7 13	23.3	23.3	3 16	25.6	23.9
8	7	24.4	22.8	2 58	25.6	23.3	7 03	24.4	22.8	3 01	26.1	23.3	7 09	23.9	23.3	3 06	25.6	23.3
9	7 05	25.0	23.3	3	26.7	24.4	7 08	25.0	23.3	3	26.7	24.4	7 14	23.3	24.4	3 08	27.2	24.4
10	7	25.6	24.4	3 05	26.7	25.0	7	25.6	24.4	3 05	26.7	25.0	7 08	25.0	23.9	3 13	27.8	25.0
11	7 05	25.6	23.9	3	27.2	26.7	7 08	25.6	23.9	3 03	27.2	26.7	7 13	25.0	23.3	3 08	27.2	26.7
12	7	26.1	23.3	3 08	27.2	25.6	7 05	26.1	23.3	3 12	27.8	25.6	7 12	25.6	23.9	3 17	27.2	25.6
13	7 02	25.6	23.9	3	27.2	25.6	7 05	26.1	23.9	3 03	27.8	25.6	7 10	26.1	24.4	3 09	27.8	25.6
14	7	25.6	24.4	3 05	27.2	27.8	7 03	26.7	24.4	3 08	27.8	27.8	7 10	26.1	24.4	3 13	27.8	27.8
15	7 08	26.1	25.0	3 08	27.8	27.8	7 11	26.7	24.4	3 12	28.9	27.8	7 16	26.7	23.9	3 18	28.9	27.8
16	7 05	26.1	23.9	3 10	27.2	26.1	7 10	26.1	23.9	3 08	28.3	26.1	7 15	26.7	24.4	3 13	28.3	26.1
17	7	26.1	24.4	3 15	28.3	27.8	7 03	26.1	24.4	3 10	28.9	27.8	7 08	26.7	25.0	3 15	28.9	27.8
18	6 58	26.7	25.0	3 04	27.8	28.9	7 02	26.7	25.0	3 07	29.4	28.9	7 10	27.8	25.0	3 10	29.4	28.9
19	7	26.7	24.4	3	28.9	27.8	7 03	27.8	24.4	3 03	28.9	27.8	7 08	26.7	24.4	3 08	28.9	27.8
20	7 05	26.7	23.9	3 05	28.3	27.8	7 08	26.7	23.9	3 08	28.3	27.8	7 12	26.7	23.9	3 14	28.3	29.8
21	7	27.2	25.0	3	28.9	26.7	7 03	27.2	25.0	3 03	28.9	26.7	7 10	27.2	27.2	3 02	28.9	26.7
22	6 57	27.2	24.4	3 08	29.4	28.9	7 03	27.2	24.4	3 10	29.4	28.9	7 08	27.2	27.2	3 15	29.4	28.9
23	7	26.7	25.0	3	28.9	27.8	7 05	26.7	25.0	3 04	29.4	27.8	7 10	26.7	26.7	3 10	29.4	27.8
24	7 03	27.2	25.6	3 05	29.4	28.9	7 08	27.2	25.6	3 08	30.0	28.9	7 13	27.2	27.2	3 12	30.0	28.9
25	7 07	26.7	24.4	3	28.3	25.6	7 05	26.7	24.4	3 03	28.9	25.6	7 10	26.7	27.2	3 08	29.4	25.6
26	7 05	26.1	25.6	3 05	27.8	24.4	7 10	26.7	25.0	3 08	28.3	24.4	7 15	26.7	26.7	3 13	28.9	24.4
27	7	26.7	25.6	3 08	26.7	26.7	7 03	27.2	25.6	3 12	27.2	26.7	7 08	27.2	27.2	3 17	27.8	26.7

Records of temperatures of surface water and of the air at Fort Jefferson, Tortugas, Florida, from June 16, 1911, to June 16, 1912—Continued.

STATIONS AT FORT JEFFERSON—Continued.

Date.	Wharf.						Moat (sally-port)						Outside moat at floodgate.					
	A. M	Temp.		P. M.	Temp.		A. M.	Temp.		P. M.	Temp.		A. M.	Temp.		P. M.	Temp.	
		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.		Water.	Air.
1912	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*	*h m*	°*C.*	°*C.*
Apr. 28	7 03	26.7	24.4	3	27.8	26.7	7 10	26.7	24.4	3 03	28.9	26.7	7 15	26.7	26.7	3 10	28.9	26.7
29	7 01	27.2	25.0	3 05	28.9	26.7	7 05	27.2	25.0	3 08	29.4	26.7	7 12	27.2	26.7	3 12	29.4	26.7
30	7 03	27.8	25.0	3 03	29.4	27.8	7 08	27.8	25.0	3 12	30.0	27.8	7 11	27.8	27.8	3 17	30.0	27.8
May 1	7	26.7	25.6	3 05	29.4	28.9	7 07	27.8	25.6	3 08	30.0	28.9	7 08	27.8	25.6	3 13	30.6	28.9
2	7 05	26.7	25.6	3	27.8	25.6	7 08	26.7	25.6	3 05	27.8	25.6	7 03	27.8	25.6	3 10	27.8	25.6
3	7	26.1	24.4	3 05	28.9	27.2	7 05	26.7	24.4	3 08	28.9	27.2	7	27.2	24.4	3 13	28.9	27.2
4	7 08	26.7	25.0	3	29.4	27.8	7 11	26.7	25.0	3 03	30.0	27.8	7 16	26.7	25.0	3 08	30.0	27.8
5	7	27.2	24.4	3 08	28.9	28.3	7 05	27.8	24.4	3 11	29.4	28.3	7 10	27.8	24.4	3 16	29.4	28.3
6	7 08	26.7	25.0	3	28.9	28.9	7 11	27.2	25.0	3 03	29.4	28.9	7 16	27.2	25.0	3 10	29.4	28.9
7	7	26.1	24.4	3 05	29.4	27.8	7 05	26.1	24.4	3 08	29.4	27.8	7 11	26.1	24.4	3 13	29.4	27.8
8	7 08	26.7	26.7	3 03	30.0	30.6	7 12	27.8	26.7	3 08	30.0	30.6	7 17	27.8	26.7	3 13	30.0	30.6
9	7	27.8	27.2	3	28.9	27.8	7 05	27.8	27.2	3 03	30.0	27.8	7 10	27.8	27.2	3 08	30.0	27.8
10	7 05	27.8	26.7	3	30.0	31.7	7 08	28.9	27.8	3 03	30.6	31.7	7 13	28.9	27.8	3 10	30.6	31.7
11	7	27.8	26.7	3 05	30.0	28.9	7 03	28.9	27.8	3 08	30.0	28.9	7 10	28.9	27.8	3 14	30.0	28.9
12	7 08	28.3	26.1	3 03	28.9	28.9	7 11	28.9	26.1	3 03	29.4	28.9	7 16	27.8	26.1	3 10	30.0	28.9
13	7	27.8	26.7	3 05	30.0	31.1	7 03	27.2	26.7	3 08	31.1	31.1	7 10	27.8	26.7	3 13	31.1	31.1
14	7 05	28.3	27.8	3	30.0	31.7	7 08	28.9	27.8	3 03	31.1	30.6	7 13	28.9	27.8	3 10	31.1	30.6
15	7	28.3	26.7	3 08	30.0	28.3	7 08	28.9	26.7	3 05	30.6	28.3	7 12	28.9	26.7	3 11	31.1	28.9
16	7	27.8	25.0	3	27.8	26.7	7 03	28.3	25.0	3 03	28.9	26.7	7 08	29.4	25.0	3 09	28.9	28.3
17	7 05	27.8	24.4	3 05	27.2	25.0	7 08	28.3	24.4	3 03	26.1	25.0	7 14	28.3	24.4	3 10	26.1	25.0
18	7 03	27.8	26.1	3 02	28.3	27.8	7 07	27.2	26.1	3 07	28.9	27.8	7 13	27.8	26.1	3 13	28.9	27.8
19	7	27.2	25.6	3	26.7	22.8	7	27.2	22.2	3 05	26.1	22.8	7	26.7	25.6	3 10	26.1	22.8
20	7 05	26.7	25.6	3 10	26.7	24.4	7 08	26.1	25.6	3 03	26.7	24.4	7 03	26.1	25.6	3 11	26.7	24.4
21	7	26.1	25.0	3 05	27.8	26.7	7 03	25.6	25.6	3 08	27.8	26.7	7 10	25.6	25.6	3 13	27.8	27.8
22	7 01	26.7	24.4	3	28.9	27.2	7 05	27.2	24.4	3 04	29.4	27.2	7 12	27.2	24.4	3 11	29.4	27.2
23	7	26.7	25.6	3 03	28.9	27.2	7 04	27.2	25.6	3 06	28.9	28.9	7 09	27.2	25.6	3 09	28.9	28.9
24	7 05	27.2	25.6	3	29.4	29.4	7 09	26.7	25.6	3 04	30.0	30.0	7 13	26.7	25.6	3 11	30.0	30.0
25	7	26.7	26.7	3 05	30.0	30.0	7 04	27.2	26.7	3 08	30.0	30.0	7 10	27.2	26.7	3 13	30.0	30.0
26	7 03	27.8	27.8	3	30.0	30.6	7 07	28.3	26.7	3 04	31.1	30.6	7 14	28.3	26.7	3 10	31.1	30.6
27	6 59	27.8	26.7	3 02	28.9	28.9	7 03	28.9	26.7	3 03	30.0	28.9	7 12	28.3	26.7	3 12	30.0	28.9
28	7	27.8	25.6	3 05	29.4	29.4	7 04	28.3	25.6	3 08	30.6	29.4	7 09	28.3	25.6	3 13	30.6	29.4
29	6 58	28.3	26.1	3	30.0	28.9	7 02	28.3	26.1	3 03	30.0	28.9	7 08	28.3	26.1	3 09	30.0	28.9
30	7	27.8	25.6	3 05	30.6	29.4	7 05	27.8	25.6	3 08	30.6	30.6	7 12	27.8	25.6	3 13	30.6	30.6
31	6 58	28.3	26.7	3	30.6	31.1	7 01	28.3	26.7	3 05	31.1	31.1	7 08	28.3	26.7	3 10	31.1	31.1
June 1	7	28.3	26.1	3	30.0	27.8	7 05	28.3	26.1	3 04	30.6	27.8	7 12	28.3	26.1	3 10	30.6	29.4
2	7 05	27.8	26.7	3 05	30.0	28.9	7 10	28.3	26.7	3 10	30.0	29.4	7 16	28.3	26.7	3 17	30.0	28.9
3	6 58	27.8	26.7	3	30.6	28.9	7 02	28.3	26.7	3 05	30.6	30.0	7 08	28.3	26.7	3 12	30.6	30.0
4	7	27.8	26.7	3 04	30.0	28.9	7 03	27.8	26.7	3 07	30.0	28.9	7 08	27.8	26.7	3 14	30.0	28.9
5	7 05	27.8	27.2	3 08	27.8	27.2	7 08	28.3	26.7	3 11	28.3	27.2	7 13	28.3	26.7	3 18	28.3	27.2
6	7 02	27.2	27.2	3	27.2	26.7	7 07	27.8	27.2	3 04	26.7	26.7	7 14	27.8	27.2	3 10	26.7	26.7
7	7	26.7	26.7	3 02	27.8	26.7	7 04	26.1	26.7	3 05	27.2	26.7	7 10	26.1	26.7	3 13	28.3	26.7
8	6 58	26.7	26.7	3 05	28.3	27.2	7 02	26.1	26.7	3 08	28.3	27.2	7 09	26.1	26.7	3 14	28.3	27.2
9	7 05	27.2	27.2	3	27.8	26.1	7 09	26.7	27.2	3 05	27.2	26.1	7 15	26.7	27.2	3 12	27.2	26.1
10	7	26.7	25.6	3 05	27.2	25.0	7 05	27.2	25.6	3 09	27.8	25.0	7 13	27.2	26.1	3 17	27.8	25.0
11	7 05	25.6	25.0	3	28.9	27.8	7 08	26.1	25.0	3 04	29.4	27.8	7 14	26.1	25.0	3 11	29.4	27.8
12	7 06	27.8	26.7	2 59	28.3	30.0	7 09	28.3	26.7	3 03	30.6	30.0	7 16	27.8	26.7	3 09	31.1	30.0
13	7 02	27.8	27.2	3	30.6	29.4	7 06	28.9	27.2	3 04	31.7	30.0	7 13	27.8	27.2	3 11	32.2	30.0
14	7	27.8	26.7	3	30.0	28.9	7 04	28.9	26.7	3 03	31.7	28.9	7 10	27.8	26.7	3 09	31.7	28.9
15	7 03	27.8	26.1	3 02	30.6	28.3	7 07	28.9	26.1	3 06	31.1	28.3	7 14	27.8	26.1	3 13	32.2	22.8
16	7	27.2	26.7	3	30.6	29.4	7 04	28.3	26.7	3 04	31.1	29.4	7 11	28.3	26.7	3 11	32.0	39.4

TEMPERATURE RECORDS FOR MEANS OF TEN-DAY PERIODS.

The readings for the following temperature records giving the means for ten-day periods and the maximum and minimum for each period, were made by the keepers at the lighthouses along the Florida reef tract. The reductions were made at the U. S. Bureau of Fisheries under the direction of Dr. H. F. Moore, who kindly supplied me a copy of the results. The significance of the data is discussed on page 321. The position of the lighthouses is shown on figure 8, page 337.

Temperature reductions to means of ten-day periods.

DRY TORTUGAS, FLORIDA.

Date.	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	C.°	°C.	°C.	°C.	°C.	°C.
Jan. 10	19.9	23.3		23.4	22.1	22.4	24.8	22.8	19.8		23.2	24.5	22.6	24.8	19.8
20	20.2	23.2	.	23.6	24.2	22.3	23.6	22.3	19.6	...	23.3	24.3	22.6	24.3	19.6
30	19.8	23.3	...	23.3	22.5	22.9	22.4	22.2	19.4	..	23.1	24.3	22.3	24.3	19.4
Feb. 9	21.6	23.6	20.9	23.4	22.5	23.0	23.4	22.4	18.9	20.3	22.9	24.3	22.3	24.3	18.9
19	21.1	23.6	22.5	23.3	23.5	23.0	23.5	21.9	19.7	22.1	23.2	24.1	22.2	24.1	19.7
Mar. 1	20.8	23.5	23.8	22.9	22.3	23.1	22.5	21.1	20.9	22.9	22.4	23.7	22.5	23.8	20.8
11	21.1	23.6	22.6	25.4	22.4	24.2	23.2	21.4	23.1	...	21.3	23.4	22.9	25.4	21.1
21	22.0	24.2	23.8	25.1	23.3	24.5	23.5	21.0	23.0	.	21.4	23.2	23.2	25.1	21.0
31	23.4	24.0	20.1	25.0	23.1	24.0	23.1	22.0	23.3		22.8	23.6	23.1	25.0	20.1
Apr. 10	22.3	23.4	18.6	24.3	24.1	23.4	23.2	22.6	17.9	.	22.4	23.7	22.4	24.3	17.9
20	22.9	23.6	22.2	25.8	23.7	22.4	24.0	22.5	18.4	.	21.9	23.7	22.9	25.8	18.4
30	23.1	23.3	24.7	25.3	23.6	22.3	24.9	23.0	23.4	.	21.4	24.7	23.6	25.3	21.4
May 10	24.5	23.6	26.3	25.4	24.0	22.9	24.7	24.2	25.7	25.9	21.9	26.4	24.5	26.4	21.9
20	24.0	23.6	25.7	23.5	27.1	23.0	25.1	25.7	25.3	26.5	24.6	26.1	25.0	27.1	23.0
30	24.0	23.6	26.0	24.1	27.2	24.1	26.0	26.7	26.9	26.4	27.0	26.9	25.8	27.2	23.6
June 9	24.0	26.0	25.6	26.9	26.1	24.1	26.4	26.8	27.5	25.9	26.7	26.3	26.0	27.5	24.0
19	23.8	27.3	25.1	27.7	28.2	24.9	26.5	27.4	25.8	26.5	27.5	26.3	26.4	28.2	23.8
29	23.6	28.0	26.0	28.2	28.2	24.7	27.0	26.7	27.2	29.3	29.3	27.8	27.2	29.3	23.6
July 9	29.6	28.7	29.2	29.0	27.4	25.1	27.6	27.5	28.7	28.2	29.4	28.6	28.3	29.6	25.1
19	30.8	29.9	29.6	28.8	28.9	25.0	28.4	28.3	28.9	28.6	29.4	29.4	28.8	30.8	25.0
29	30.7	31.1	29.9	28.7	29.3	24.7	28.3	28.3	28.6	28.4	29.8	29.6	29.0	31.1	24.7
Aug. 8	30.8	30.6	29.2	28.4	28.9	24.8	28.9	28.7	29.0	29.8	29.2	29.2	29.0	30.8	24.8
18	30.9	29.4	29.3	28.5	29.0	24.8	29.3	28.8	29.7	29.6	28.7	29.2	29.0	30.9	24.8
28	30.0	29.1	29.4	28.6	29.3	24.2	29.3	28.9	29.6	29.6	28.7	29.0	28.8	30.0	24.2
Sept. 7	29.0	28.6	28.8	28.5	28.7	23.5	28.8	28.4	28.7	29.5	28.9	29.6	28.4	29.6	24.1
17	28.4	29.5	29.1	27.4	29.0	23.7	28.6	27.6	29.7	29.4	29.2	28.9	28.4	29.7	24.3
27	27.9	30.5	29.0	29.2	28.7	25.4	27.7	28.1	28.6	28.9	28.8	29.1	28.5	30.5	25.4
Oct. 7	27.4	29.4	28.7	29.0	28.9	23.7	27.2	28.1	27.1	28.0	28.1	28.9	27.9	29.4	23.7
17	27.1	27.5	28.5	26.3	28.3	22.5	25.4	27.5	27.0	27.4	26.3	29.0	26.9	29.0	22.5
27	26.7	26.9	27.2	27.0	27.4	24.8	24.3	27.8	27.1	27.2	26.8	28.3	26.8	28.3	24.3
Nov. 6	27.0	25.8	28.0	26.9	27.1	25.7	23.7	27.8	.	27.1	27.1	26.1	26.5	28.0	23.6
16	26.4	25.8	27.2	26.2	26.1	23.9	23.6	27.8		26.2	26.6	26.0	26.0	27.8	23.6
26	21.4	24.6	27.1	22.6	25.4	23.4	22.6	26.2	..	25.9	25.8	25.3	24.5	27.1	21.4
Dec. 6	22.9	24.8	26.4	21.5	25.3	23.3	21.5	22.6	23.2	24.7	23.1	24.3	23.6	26.4	21.5
16	23.2	22.9	25.8	21.3	24.6	24.5	22.2	24.4	23.0	23.1	23.2	23.8	23.5	25.8	21.3
31	23.3	22.1	24.5	21.9	25.2	25.9	22.7	22.2	23.4	22.7	23.4	21.8	23.2	25.9	21.8

Temperature reductions to means of ten-day periods—Continued.

DRY TORTUGAS, FLORIDA—Continued.

Date.	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Jan. 10	21.2	23.0	20.2	23.4	24.2	20.9	21.8	19.9	22.6	21.0	23.4	19.8	21.8	24.2	19.8
20	21.1	23.2	19.9	23.0	22.1	21.6	22.2	22.2	24.1	21.0	21.9	19.5	21.9	24.1	19.5
30	21.2	23.1	19.0	22.2	22.1	21.2	20.4	23.7	22.0	20.2	20.3	19.4	21.2	23.7	19.0
Feb. 9	24.0	23.3	21.0	22.5	21.4	22.0	21.3	21.1	22.4	19.7	21.3	21.6	21.8	24.0	19.7
19	24.4	22.8	23.3	22.4	18.7	20.9	22.4	22.9	20.1	20.9	22.9	20.7	21.9	24.4	18.7
Mar. 1	24.7	22.6	23.8	22.1	19.6	20.8	22.6	22.0	21.1	19.6	22.2	20.3	21.8	23.8	19.6
11	24.1	22.6	24.7	22.5	22.3	21.9	23.0	22.4	20.5	21.2	21.1	19.6	22.2	24.7	19.6
21	23.9	23.0	23.9	24.1	23.4	20.8	24.6	24.6	21.8	22.9	21.4	22.8	23.1	24.6	20.8
31	23.7	23.1	24.0	24.0	23.2	21.4	24.4	24.8	25.7	23.5	22.2	23.9	23.5	24.8	21.4
Apr. 10	22.4	23.6	24.3	24.7	23.4	22.2	24.6	24.6	23.8	22.9	23.4	23.0	23.6	24.7	22.2
20	23.5	24.9	25.5	25.2	23.6	24.7	24.2	24.2	23.5	24.1	23.6	23.4	24.2	25.5	23.4
30	23.3	25.7	25.5	25.4	24.5	25.8	25.1	25.7	24.9	24.3	23.1	23.4	24.7	25.8	23.1
May 10	23.8	25.5	26.2	25.9	26.4	26.4	24.4	25.9	25.4	24.7	24.6	24.3	25.3	26.4	23.8
20	24.6	26.3	27.3	26.3	26.5	26.8	25.7	26.2	27.2	25.2	27.0	24.8	26.1	27.3	24.6
30	25.1	27.0	27.9	26.7	27.2	26.3	26.8	27.3	28.3	25.2	27.2	26.8	26.8	28.3	25.1
June 9	25.8	27.0	28.2	28.0	26.3	27.0	27.4	27.5	28.5	26.2	28.3	27.0	27.2	23.0	25.8
19	25.8	27.3	28.0	27.4	27.3	27.9	28.0	28.3	28.6	27.9	28.4	27.0	27.6	28.6	25.8
29	28.3	27.6	29.1	27.5	28.1	28.5	29.1	29.3	28.6	28.4	29.0	28.2	28.5	29.3	27.5
July 9	29.4	27.7	29.6	28.1	28.3	27.9	29.5	29.4	29.1	29.0	28.6	28.6	28.7	29.6	27.7
19	29.6	28.1	30.2	28.7	29.1	27.5	29.2	28.7	29.1	28.4	28.7	29.5	28.9	30.2	27.5
29	29.3	29.1	29.8	29.3	29.2	28.9	29.3	29.5	29.1	28.5	29.0	29.2	29.2	29.8	28.5
Aug. 8	30.0	30.1	30.2	29.5	29.7	29.5	29.0	29.9	29.5	29.2	29.0	29.6	29.6	30.2	29.0
18	29.5	29.5	30.3	29.5	29.3	29.7	30.0	29.6	29.7	29.3	28.7	29.6	29.5	30.3	29.3
28	29.4	29.9	30.1	29.9	29.2	30.2	30.0	30.2	29.8	29.3	28.8	29.9	29.7	30.2	28.8
Sept. 7	29.4	30.1	30.1	30.1	29.3	30.1	29.4	29.3	29.9	28.4	29.2	29.2	29.5	30.1	28.4
17	29.4	30.0	29.7	29.2	29.5	29.8	28.2	29.0	29.8	28.4	28.8	29.1	29.3	30.0	28.2
27	28.2	29.2	29.3	28.6	28.7	28.1	28.1	29.6	29.7	29.0	28.9	29.1	28.9	29.7	28.1
Oct. 7	27.5	27.6	29.3	26.3	28.0	27.9	27.5	29.3	28.3	28.8	28.4	29.2	28.2	29.3	26.3
17	26.4	26.9	28.1	26.1	27.8	26.5	27.2	28.2	28.3	28.5	28.3	28.6	27.5	28.6	26.1
27	24.6	27.0	26.9	25.4	25.9	27.3	26.9	26.5	27.2	27.9	27.1	27.9	26.7	27.9	24.6
Nov. 6	23.6	25.1	26.1	24.6	27.0	27.4	26.0	25.4	25.7	27.1	25.8	25.1	25.8	27.4	23.6
16	23.7	24.5	25.9	22.2	25.4	26.2	25.2	25.8	24.5	25.6	25.0	24.7	24.8	26.2	22.2
26	23.4	21.4	25.5	23.4	24.5	25.2	24.4	24.6	24.6	25.7	23.2	24.8	24.2	25.7	21.4
Dec. 6	23.8	21.3	24.7	22.7	23.8	24.5	24.3	23.7	23.7	23.6	23.1	24.1	23.6	24.5	21.3
16	23.5	22.9	23.9	23.7	22.3	24.2	23.5	21.5	23.2	22.6	22.7	23.2	23.1	24.2	21.5
31	23.5	21.9	22.6	21.6	23.0	22.2	22.4	22.7	22.5	23.2	20.6	21.4	22.3	23.5	20.6

Date.	1903	1904	1905	1906	1907	Date.	1903	1904	1905	1906	1907
	°C.	°C.	°C.	°C.	°C.		°C.	°C.	°C.	°C.	°C.
Jan. 10	21.1	21.3	20.7	20.8	21.2	July 9	28.2	27.3	29.0	29.5	....
20	20.0	19.8	20.4	21.5	21.8	19	28.7	28.3	29.1	29.6	....
30	21.1	22.4	19.9	20.5	21.8	29	29.3	28.4	29.2	29.5	....
Feb. 9	23.1	22.3	22.1	20.6	23.2	Aug. 8	29.4	28.6	29.4	28.7	....
19	23.0	22.7	23.0	21.3	21.4	18	29.8	29.0	29.7	29.5	....
Mar. 1	22.2	23.0	21.8	21.4	21.4	28	29.8	28.5	29.6	29.4	....
11	23.6	23.3	23.1	21.5		Sept. 7	31.1	28.7	29.0	29.1	....
21	24.4	23.7	23.1	22.3	....	17	29.5	29.1	29.5	29.7	....
31	24.2	24.3	23.6	22.1	....	27	28.6	28.9	29.3	29.1	....
Apr. 10		24.7	23.2	21.9	....	Oct. 7	27.8	29.2	27.6	28.3	....
20		24.0	23.3	24.0	....	17	27.4	28.0	27.6	26.9	....
30		24.8	24.2	24.5		27	26.0	25.3	28.6	25.3	....
May 10	24.9	25.3	24.3	28.4		Nov. 6	23.9	23.7	27.0	26.1	....
20	25.9	25.2	26.9	27.1		16	25.1	23.9	25.8	24.3	....
30	26.0	26.0	27.9	28.1	....	26	24.0	23.0	25.4	24.7	....
June 9	27.5	28.6	28.1	28.6	....	Dec. 6	22.3	22.6	25.4	22.8	....
19	28.1	27.3	28.1	27.8	....	16	22.0	23.7	....	23.0	....
29	28.3	27.3	28.3	28.2	....	31	21.3	21.5	22.7	21.5	....

Temperature reductions to means of ten-day periods—Continued.

KEY WEST, FLORIDA.

Date.	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Jan. 10	18.4	19.8	23.4	21.8	20.1	23.3	20.8	23.7	20.1	19.6	23.5	22.0	23.0	21.5	23.8	18.3
20	19.1	25.6	23.3	23.1	23.4	22.5	21.8	24.1	17.9	20.5	23.5	22.2	23.5	22.1	24.1	17.9
30	20.1	19.8	23.3	22.0	24.0	23.9	20.3	22.6	20.0	21.2	22.6	22.8	23.6	22.0	24.0	19.8
Feb. 9	20.2	21.8	24.0	22.1	24.3	24.9	22.7	22.2	18.6	24.2	23.6	20.7	23.5	22.4	24.9	18.3
19	21.9	22.3	24.4	22.2	24.4	25.3	24.6	21.1	20.7	24.5	24.3	22.2	23.5	23.2	25.3	20.8
Mar. 1	22.0	21.9	24.4	22.9	23.2	24.4	24.2	22.4	23.0	25.7	24.1	23.0	23.6	23.4	25.7	21.9
11	21.5	22.6	25.9	21.4	....	23.1	23.7	22.6	23.7	24.0	....	22.2	20.4	22.9	25.9	20.4
21	23.2	23.9	26.9	25.1	....	25.3	25.6	24.2	24.8	23.3	....	21.9	22.2	24.2	26.9	21.9
31	25.4	26.8	25.4	21.6	....	24.6	27.3	25.3	23.1	23.5	24.2	23.5	26.6	24.7	27.3	21.6
Apr. 10	25.0	25.1	25.4	22.5	28.2	25.9	27.7	....	23.3	....	26.8	24.3	26.5	25.5	28.2	22.5
20	28.1	25.9	25.9	23.7	27.3	27.6	27.1	24.9	25.9	...	26.4	25.6	25.4	26.2	28.1	23.7
30	26.5	21.8	27.9	27.3	28.3	26.4	26.2	26.3	28.5	....	25.3	26.1	25.6	26.6	28.5	25.1
May 10	26.6	28.5	28.0	27.6	29.4	28.2	28.0	29.4	26.4	....	25.8	25.9	28.4	27.6	29.4	25.8
20	29.7	29.5	26.6	27.4	28.1	27.4	29.0	29.3	28.6	....	27.5	29.0	27.4	28.3	29.6	26.6
30	29.2	28.5	26.4	28.6	27.2	28.3	29.9	29.3	28.9	....	29.8	28.6	28.5	28.6	29.9	26.4
June 9	31.0	28.4	29.0	29.9	....	29.2	28.3	28.0	30.3	27.7	28.7	28.6	29.3	29.1	31.0	27.7
19	32.2	30.1	30.1	30.6	....	29.6	30.1	30.5	30.8	28.1	29.0	28.5	29.7	29.9	32.2	28.1
29	29.5	28.5	30.2	29.8	....	31.5	29.0	31.3	30.5	30.0	31.3	31.0	31.1	30.3	31.5	28.5
July 9	30.5	29.9	30.5	30.8	31.8	30.8	31.1	31.4	30.8	30.4	....	30.5	30.2	30.8	31.8	29.9
19	31.4	31.9	31.1	31.1	30.3	31.7	30.8	31.8	30.8	31.1	....	30.3	30.8	31.1	31.9	30.3
29	31.3	31.8	31.7	31.8	30.9	31.5	31.4	31.4	31.2	31.5	....	31.1	31.0	31.4	31.8	30.9
Aug. 8	31.3	30.7	30.0	30.8	....	31.5	....	31.7	31.3	31.3	32.2	29.7	29.4	30.9	32.2	29.4
18	31.5	31.8	29.4	30.3	....	30.8	....	31.5	30.4	31.5	30.6	29.2	30.9	30.7	31.8	39.2
28	31.1	30.8	....	31.3	....	31.1	....	31.1	29.8	31.3	30.2	29.0	29.7	30.6	31.3	29.0
Sept. 7	31.2	30.2	....	30.3	....	30.3	....	31.2	30.0	29.8	29.8	29.3	30.2	31.4	31.2	29.3
17	29.0	30.1	30.0	30.1	....	31.0	....	31.1	30.9	29.8	29.8	29.7	30.1	30.1	31.1	29.0
27	29.3	29.4	29.3	29.4	....	30.4	....	31.0	28.9	28.7	29.2	29.3	29.6	29.5	31.0	28.7
Oct. 7	28.5	28.4	28.1	....	29.0	30.1	28.5	29.5	28.7	29.2	27.5	29.2	29.7	28.9	30.1	27.5
17	28.2	27.5	26.4	....	28.5	28.6	27.6	28.0	27.9	27.3	26.2	26.0	29.7	27.2	29.7	26.0
27	30.1	27.5	28.6	....	28.1	27.1	25.4	26.1	26.3	27.7	26.6	25.7	28.0	26.8	28.6	24.5
Nov. 6	24.0	26.0	26.4	....	26.5	25.8	25.7	25.1	25.3	24.7	27.1	26.8	....	25.8	27.1	24.0
16	24.7	25.8	26.2	....	24.9	25.7	24.7	25.3	24.5	24.8	25.6	26.9	....	25.4	26.9	24.5
26	24.3	22.3	25.0	....	23.2	25.5	24.7	23.1	25.3	23.6	24.7	23.9	....	24.2	25.5	22.3
Dec. 6	21.4	23.3	26.0	24.2	21.9	23.3	24.1	20.7	21.9	22.3	22.7	22.0	....	22.9	26.0	20.7
16	20.5	24.4	21.2	24.3	23.4	23.1	25.0	21.8	20.9	23.4	20.6	22.3	....	22.5	25.0	20.5
31	20.3	24.5	21.3	22.4	22.5	24.0	24.4	18.4	22.0	23.4	19.5	22.6	....	22.1	24.5	18.4

CARYSFORT REEF, FLORIDA.

Date.	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Jan. 10	....	20.1	24.7	24.0	24.8	23.6	23.4	24.1	22.2	22.4	24.2	21.5	22.6	23.2	24.8	20.1
20	....	20.4	24.5	24.1	25.9	22.9	24.3	23.9	20.9	22.1	24.1	22.8	23.4	23.3	25.9	20.4
30	....	22.1	24.5	24.1	24.8	22.4	23.2	23.6	21.4	21.9	24.1	23.1	23.4	23.2	24.8	21.4
Feb. 9	....	22.9	24.4	24.3	24.5	21.9	24.3	22.2	20.6	23.5	23.6	21.8	23.5	23.1	24.5	20.6
19	....	22.7	24.4	23.6	23.9	23.4	24.8	22.1	21.8	23.7	23.5	23.1	23.5	23.4	24.8	21.8
Mar. 1	...	22.3	24.0	23.4	23.6	23.5	24.7	22.3	22.5	23.8	23.5	23.3	23.2	23.4	24.7	22.3
11	....	22.3	24.4	22.8	24.2	....	24.8	22.9	22.5	23.5	23.2	23.7	21.5	23.3	24.8	21.5
21	....	23.3	25.3	23.3	24.3	...	25.1	23.2	22.4	22.4	22.5	23.6	21.7	23.4	25.3	21.7
31	....	24.1	25.6	22.8	24.3	...	25.0	22.7	23.0	22.3	23.4	22.8	23.2	23.5	25.6	22.3
Apr. 10	...	22.8	25.3	22.9	24.2	24.0	24.8	24.6	23.1	22.9	24.9	23.0	23.3	23.8	25.3	22.8
20	...	23.0	25.5	24.7	24.2	25.1	25.3	24.5	24.0	23.7	24.9	23.7	23.5	24.4	25.5	23.0
30	....	22.6	26.4	24.8	25.1	25.7	24.7	25.0	24.9	25.3	24.7	24.8	23.4	24.8	26.4	22.6
May 10	....	25.8	26.8	26.0	26.1	26.5	25.7	26.5	25.7	25.4	25.1	25.3	24.0	25.8	26.8	24.0
20	....	26.5	26.5	26.5	26.0	26.4	27.0	26.8	26.8	25.5	25.7	26.5	24.0	26.2	27.0	24.0
30	....	26.6	26.3	26.8	26.1	26.9	27.9	26.8	26.8	26.4	26.4	26.6	25.1	26.5	27.9	25.1
June 9	....	27.2	27.1	28.4	27.2	27.7	27.9	26.8	27.4	26.4	27.0	27.8	25.9	27.2	28.4	25.9
19	....	28.1	28.2	29.4	27.9	28.5	28.8	27.8	28.1	26.5	27.3	27.9	26.8	28.0	29.4	26.5
29	....	27.7	28.7	28.7	28.2	29.1	28.4	28.4	28.4	28.1	28.4	28.2	27.0	28.3	29.1	27.0

Temperature reductions to means of ten-day periods—Continued.

CARYSFORT REEF, FLORIDA—Continued.

Date.	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
July 9	...	27.8	28.8		28.7	28.7	29.1	28.6	28.5	28.3	28.7	27.9	27.1	28.4	29.1	27.1
19	...	29.0	29.0		29.0	29.4	29.7	29.4	28.6	29.6	29.2	28.2	27.1	29.0	29.7	27.1
29		29.4	29.5		28.5	29.4	29.1	29.4	28.7	29.6	29.5	28.7	27.3	29.1	29.6	27.3
Aug. 8	....	29.3	29.6		28.8	29.3	28.9	30.2	29.1	29.5	30.3	28.8	26.5	29.2	30.3	26.5
18	.	29.8	29.1		29.0	29.3	29.2	30.2	28.7	30.0	30.1	28.6	27.3	29.3	30.2	27.3
28	. .	29.6	29.3	..	28.6	29.5	29.0	30.3	28.5	29.7	29.5	28.4	27.3	29.1	30.3	27.3
Sept. 7	....	29.0	28.4	..	28.9	29.1	29.3	30.1	28.4	29.3	29.3	28.1	27.5	28.9	30.1	27.5
17	28.6	29.3	29.1		28.9	29.1	28.9	29.9	28.4	29.5	29.1	28.3	27.2	28.9	29.9	27.2
27	28.0	29.4	29.2		28.6	28.7	28.6	29.5	28.2	28.4	29.3	27.9	27.1	28.6	29.5	27.1
Oct. 7	27.5	28.1	28.7	26.3	27.7	29.0	28.1	29.1	28.2	28.1	28.5	27.4	27.0	28.1	29.1	26.3
17	27.2	27.3	28.2	26.8	28.2	28.5	28.2	27.6	27.7	27.3	26.9	26.5	27.1	27.5	28.5	26.5
27	25.9	27.6	27.1	27.1	27.0	28.1	26.9	27.1	26.8	27.4	27.2	25.5	26.9	27.1	28.1	25.5
Nov. 6	24.4	27.0	27.2	26.5	26.0	26.9	26.9	25.0	24.3	26.4	27.1	26.0	24.4	26.2	27.2	24.3
16	25.1	26.4	26.7	26.8	24.7	27.7	25.8	25.1	24.4	25.7	26.7	27.3	25.1	26.0	27.7	24.4
26	25.0	26.0	26.2	25.9	24.4	27.7	26.0	24.1	24.5	24.6	25.8	26.0	24.4	25.4	28.7	24.1
Dec. 6	23.5	24.8	26.4	25.8	23.3	27.3	25.2	22.3	23.5	23.9	..	25.4	24.0	24.7	27.3	22.3
16	23.4	24.9	24.8	24.5	24.4	26.0	24.6	22.8	22.7	24.4	..	23.5	22.4	24.1	26.0	22.4
31	22.2	25.2	24.1	24.0	23.2	25.1	24.6	21.9	22.5	23.6	.	22.2	21.0	23.4	25.2	21.0

Date.	1891	1892	1893	1894	1895	1896	1897	1898	1899	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Jan. 10	20.5	21.8	18.7	23.5	22.8	22.0	22.7	22.8	21.1	21.8	23.5	18.7
20	19.9	22.3	18.2	21.8	22.1	22.2	23.8	24.1	21.5	21.8	24.1	18.2
30	20.4	22.0	19.8	22.1	21.8	22.8	22.1	24.1	21.0	21.8	24.1	19.8
Feb. 9	22.8	22.2	22.9	22.7	21.7	22.6	22.4	22.2	24.6	22.6	24.6	21.7
19	23.2	22.1	23.5	23.2	21.3	22.6	22.5	21.9	24.2	22.7	24.2	21.3
Mar. 1	22.1	22.3	23.2	23.2	21.1	21.9	23.6	22.5	24.4	22.7	24.4	21.1
11	22.5	22.4	22.9	22.5	22.0	22.0	23.6	22.0	24.3	22.7	24.3	22.0
21	22.3	22.5	22.6	23.7	22.7	22.2	24.4	22.6	24.4	23.1	24.4	22.2
31	22.0	22.1	22.4	22.4	22.2	22.5	23.7	23.5	25.2	22.9	25.2	22.0
Apr. 10	22.4	23.2	22.5	22.8	22.6	23.6	25.3	23.5	23.5	23.3	25.3	22.4
20	23.0	24.1	24.2	23.4	23.1	24.3	24.2	24.1	24.6	23.9	24.6	23.0
30	23.7	24.1	24.9	23.6	23.5	26.1	24.4	24.8	25.3	24.5	26.1	23.5
May 10	23.7	24.4	26.2	23.8	24.7	24.2	24.7	24.6	24.7	24.5	26.2	23.7
20	23.3	25.0	25.7	24.3	25.7	26.5	25.2	25.8	26.3	25.2	26.5	23.3
30	24.2	26.0	26.0	24.7	27.1	26.4	25.9	25.9	26.7	25.2	27.1	24.2
June 9	25.4	25.9	26.8	25.4	27.0	27.0	26.6	26.9	26.3	26.4	27.0	25.4
19	26.3	25.9	28.0	26.8	27.5	27.1	27.8	27.4	26.6	27.1	28.0	25.9
29	27.4	26.0	28.1	27.4	28.3	29.1	29.2	28.1	27.0	27.9	29.2	26.0
July 9	27.9	27.5	28.1	28.0	29.2	28.6	29.6	28.2	28.4	28.4	29.6	27.5
19	27.2	28.1	29.0	29.0	30.2	28.5	29.4	29.6	29.3	29.0	30.2	27.2
29	27.3	28.1	29.3	28.4	29.5	29.2	29.2	29.5	28.7	28.8	29.5	27.3
Aug. 8	28.0	28.1	29.1	29.0	29.4	29.2	29.4	29.5	29.0	29.0	29.5	28.0
18	28.0	28.3	29.6	29.6	28.3	29.0	29.8	29.5	29.6	29.1	29.8	28.0
28	27.7	28.5	29.0	30.0	29.4	29.6	29.8	29.4	29.8	28.1	30.0	27.7
Sept. 7	27.7	28.4	28.7	29.6	29.3	29.3	29.5	29.7	29.4	29.1	29.7	27.7
17	28.1	28.6	28.9	29.8	29.3	28.5	28.6	29.6	29.3	29.0	29.8	28.1
27	27.2	28.1	28.4	28.0	28.5	28.4	28.6	29.7	29.3	28.4	29.3	27.2
Oct. 7	26.1	27.3	27.8	27.5	27.9	28.1	27.6	28.5	28.6	27.7	28.6	26.1
17	25.5	27.4	26.3	26.4	28.5	26.8	28.5	28.2	27.3	27.2	28.5	25.5
27	23.8	26.2	26.0	25.2	26.4	27.0	27.2	25.8	26.8	26.0	27.2	23.8
Nov. 6	24.1	26.1	25.7	25.7	26.7	27.0	25.8	25.6	26.0	25.8	27.0	24.1
16	23.7	24.7	24.7	24.3	25.9	26.4	25.2	24.9	24.0	24.8	26.4	23.7
26	23.6	23.0	25.1	25.7	23.3	25.8	24.6	24.8	23.9	24.4	25.8	23.0
Dec. 6	24.0	22.5	24.4	24.6	23.8	25.3	25.4	25.2	24.1	24.3	25.4	22.5
16	24.4	24.5	24.4	25.0	22.6	24.4	24.8	22.9	24.0	24.1	25.0	22.6
31	23.2	23.1	23.5	22.6	22.7	24.2	24.4	22.3	23.6	23.3	24.4	22.3

Temperature of reductions to means of ten-day periods—Continued.

FOWEY ROCKS, OFF COCOANUT GROVE, FLORIDA.

Date.	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Jan. 10	....	...	23.4	22.9	24.0	23.0	23.7	22.5	20.9	24.0	22.9	23.3	23.1	24.0	20.9
20	...	..	23.2	23.4	23.4	23.3	24.0	21.0	22.0	23.7	23.6	23.9	23.2	24.0	21.0
30	...	...	22.5	23.5	23.5	22.9	23.7	21.2	22.3	23.6	22.0	23.7	23.0	23.7	21.2
Feb. 9	..	23.3	23.0	23.6	23.9	23.7	22.3	20.3	23.7	24.1	21.6	24.3	23.1	24.3	20.3
19	....	24.1	23.2	23.6	24.5	24.0	21.9	21.6	24.2	23.1	22.4	24.2	23.3	24.5	21.6
Mar. 1	22.8	23.5	23.9	22.6	24.2	23.1	22.0	22.3	24.5	22.5	23.0	24.0	23.2	24.5	22.0
11	22.5	24.4	22.5	23.8	23.5	22.7	21.2	22.3	23.7	22.8	22.2	22.5	22.9	24.4	21.2
21	22.9	23.5	22.9	24.2	23.4	24.1	21.8	22.7	22.6	22.4	22.9	23.0	23.1	24.2	21.8
31	23.6	22.8	21.3	24.4	23.2	24.0	22.6	23.0	22.3	23.0	23.3	24.3	23.2	24.4	21.3
Apr. 10	26.7	23.8	22.0	24.8	24.8	23.8	24.5	22.9	23.1	24.3	23.2	24.6	24.1	26.7	22.0
20	26.9	24.3	23.6	25.7	25.2	24.5	25.1	23.7	24.3	24.4	24.0	24.0	24.6	26.9	23.6
30	26.8	25.1	25.3	26.0	25.6	24.6	24.8	24.7	25.3	23.8	23.6	24.3	25.0	26.8	23.6
May 10	26.6	25.1	25.8	25.2	25.6	25.2	25.8	25.7	25.3	24.2	25.4	26.1	25.5	26.6	24.2
20	27.6	25.3	26.2	26.0	26.1	25.8	27.2	26.9	25.3	24.3	26.0	25.8	26.1	27.6	24.3
30	27.4	25.8	26.8	26.3	25.7	26.5	27.0	26.8	26.3	24.6	26.7	26.9	26.4	27.4	24.6
June 9	27.2	26.6	27.8	27.7	26.8	26.5	26.8	27.5	27.0	25.5	27.3	27.6	27.1	27.8	25.5
19	27.4	27.5	28.9	28.0	28.3	27.0	27.6	28.4	27.1	26.8	27.4	28.5	27.7	28.9	26.8
29	27.3	28.5	28.0	28.8	28.5	27.3	27.7	28.9	27.7	29.1	28.5	28.9	28.3	29.1	27.3
July 9	25.4	28.9	29.1	29.4	28.4	28.0	28.5	29.1	28.4	29.4	28.3	28.7	28.5	29.4	25.4
19	24.6	29.0	29.2	29.4	29.1	28.5	29.3	28.5	29.3	30.2	29.0	28.6	28.7	30.2	24.6
29	24.3	29.3	28.6	29.0	29.5	29.3	29.3	28.5	29.8	30.3	29.3	29.3	29.0	30.3	24.3
Aug. 8	24.8	29.6	29.3	28.6	29.2	29.1	30.1	29.0	29.8	30.9	29.4	29.2	29.1	30.9	24.8
18	25.0	29.1	29.1	29.4	29.3	29.1	30.2	28.7	29.8	29.8	29.1	29.3	29.0	30.2	25.0
28	24.8	28.2	28.8	29.0	29.8	28.8	29.7	28.6	29.6	29.3	28.8	29.6	28.7	29.8	24.8
Sept. 7	25.2	28.1	28.7	28.7	28.7	29.3	29.4	28.7	28.7	28.5	28.4	29.3	28.5	29.4	25.2
17	24.6	28.5	28.7	28.5	28.8	28.8	29.7	29.3	29.0	28.5	28.1	29.3	28.5	29.7	24.6
27	24.4	28.6	28.2	28.4	29.3	28.6	29.7	28.3	28.3	27.2	28.0	28.8	28.2	29.7	24.4
Oct. 7	...	28.3	27.9	28.1	29.0	28.0	28.7	27.7	28.4	26.6	27.4	28.4	28.1	29.0	26.6
17	....	28.9	26.8	28.1	27.9	27.0	27.2	27.5	28.2	26.3	26.9	28.5	27.5	28.9	26.3
27	...	25.8	27.1	27.3	26.6	26.5	26.4	26.8	27.5	26.3	26.5	27.3	26.8	27.5	25.8
Nov. 6	..	26.0	26.1	26.2	26.4	25.7	25.3	25.6	26.2	26.5	26.1	25.8	26.0	26.5	25.3
16	...	26.5	25.9	25.3	25.5	25.4	24.8	25.0	25.3	26.9	26.1	25.7	25.7	26.9	24.8
26	....	25.7	25.9	24.3	25.4	25.2	23.1	24.4	24.5	24.1	25.2	25.5	24.8	25.9	23.1
Dec. 6	...	26.2	25.5	23.6	24.6	24.4	21.8	23.4	24.5	23.0	24.4	24.3	24.2	26.2	21.8
16	....	24.1	25.2	24.2	24.2	24.3	23.0	21.9	24.2	23.5	24.1	23.6	23.8	25.2	21.9
31	...	23.0	23.8	23.3	24.2	24.1	22.2	22.5	23.7	22.2	24.1	22.1	23.2	24.2	22.1

Date.	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Jan. 10	.	22.9	22.6	23.3	22.3	19.6	20.1	20.8	20.7	18.0	21.9	18.2	21.0	23.3	18.0
20	.	23.3	20.8	23.4	22.7	19.3	22.4	22.4	23.3	20.8	21.2	15.8	21.4	23.4	15.8
30	.	23.0	22.0	23.1	23.2	23.0	20.2	22.6	21.8	20.2	20.3	19.9	21.8	23.2	19.9
Feb. 9	24.3	22.4	23.5	23.1	21.1	22.9	21.2	21.2	23.0		18.7	22.0	22.1	24.3	18.7
19	24.5	23.0	23.9	23.1	20.2	21.0	22.3	22.3	15.6	.	21.4	20.4	21.5	24.5	15.6
Mar. 1	23.9	22.6	23.6	23.4	19.9	20.2	22.1	21.0	22.1	...	18.7	19.5	21.5	23.9	18.7
11	23.6	22.9	23.6	23.1	23.3	22.4	22.4	21.4	21.9	....	21.2	20.5	22.4	23.6	20.5
21	24.0	22.6	23.7	23.4	22.9	21.1	23.6	23.0	23.0	....	19.6	21.3	22.5	24.0	19.6
31	23.8	23.0	23.3	23.0	22.8	23.4	23.3	23.2	23.3	...	22.7	22.1	23.1	23.8	22.1
Apr. 10	23.7	23.5	23.6	23.7	24.0	23.1	23.2	26.3	24.2	21.5	24.1	21.0	23.5	26.4	21.0
20	25.3	24.1	24.3	23.9	23.5	24.1	22.3	25.2	24.7	21.9	24.3	22.5	23.8	25.3	21.9
30	25.4	25.0	25.0	24.3	23.8	24.6	23.2	24.0	25.8	23.6	24.2	23.0	24.3	25.8	23.0
May 10	25.3	24.9	25.5	24.3	25.3	25.3	23.6	24.2	24.7	23.9	23.3	23.5	24.4	25.5	22.3
20	25.7	25.3	25.6	24.7	25.9	26.3	23.5	24.5	27.6	23.4	24.0	23.6	25.0	27.6	23.4
30	26.3	26.3	26.0	25.3	25.9	27.6	25.7	26.8	28.2	23.8	23.4	23.3	25.7	28.2	23.3
June 9	26.6	26.3	28.4	26.2	25.9	27.9	26.7	26.8	27.6	24.8	22.7	23.3	26.0	27.9	22.7
19	27.5	25.9	27.8	26.2	26.2	27.6	27.9	27.5	27.7	24.7	23.3	23.4	26.3	27.9	23.3
29	28.4	27.2	29.3	27.4	26.8	28.8	29.2	28.3	28.1	25.7	24.1	23.6	27.2	29.3	23.6

Temperature reductions to means of ten-day periods—Continued.

FOWEY ROCKS, COCOANUT GROVE, FLORIDA—Continued.

Date.	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
July 9	29.3	28.0	29.5	28.0	27.3	28.8	29.8	28.5	28.3	27.1	23.5	24.5	27.7	29.8	23.5
19	29.1	28.4	29.7	28.1	28.4	30.0	29.5	29.1	28.0	27.6	24.5	24.4	28.1	30.0	24.4
29	29.5	28.7	29.6	28.8	28.7	30.7	29.3	29.5	28.3	28.2	23.5	24.6	28.2	30.7	23.5
Aug. 8	29.6	29.0	29.8	29.7	28.8	30.7	30.0	29.4	28.7	27.6	28.2	23.6	28.7	30.7	23.6
18	29.1	28.9	29.7	29.9	28.7	30.1	31.2	29.5	28.2	27.2	27.3	23.7	28.6	31.2	23.7
28	29.3	29.1	29.1	29.8	28.6	30.2	30.8	29.2	29.4	27.5	27.9	23.5	28.6	30.8	23.5
Sept. 7	29.0	29.0	29.2	29.5	28.8	30.4	28.7	30.1	28.3	27.0	27.8	22.9	28.4	30.4	22.9
17	28.6	29.0	29.3	29.1	29.3	30.1	28.3	30.7	27.6	27.2	27.4	23.5	28.3	30.7	23.5
27	28.4	28.6	28.2	29.0	29.6	29.7	27.8	29.5	28.2	27.6	27.3	24.0	28.2	29.7	24.0
Oct. 7	27.7	27.5	27.8	28.1	28.2	29.3	25.9	29.1	26.8	26.0	27.0	24.2	27.3	29.3	24.2
17	26.7	27.3	27.1	25.9	26.5	28.1	25.8	28.5	27.3	25.8	27.5	23.6	26.6	28.5	23.6
27	24.7	26.8	26.1	24.7	23.4	26.5	25.9	26.1	26.6	26.3	26.0	22.5	25.4	26.8	22.5
Nov. 6	24.2	24.6	25.4	24.6	24.1	28.0	25.2	24.4	26.4	26.3	25.1	23.3	25.2	28.0	23.3
16	24.3	23.7	24.4	23.5	25.3	28.4	24.1	23.5	25.1	22.1	22.2	24.6	24.3	28.4	22.1
26	24.4	23.4	24.7	24.2	23.6	27.0	23.7	23.5	25.3	23.1	20.0	24.7	24.0	27.0	20.0
Dec. 6	24.6	23.7	24.5	23.5	22.8	24.4	24.0	22.2	23.5	22.4	21.0	24.2	23.4	24.6	21.0
16	24.6	24.2	23.6	24.0	18.5	21.9	23.5	15.8	23.0	21.6	21.4	24.9	22.2	24.9	15.8
31	23.3	23.3	23.3	22.2	24.7	21.4	23.1	18.3	21.1	21.4	18.2	21.8	21.9	24.7	18.2

Date.	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	Mean.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Jan. 10	21.0	21.4	21.4	22.2	22.8	22.4	25.3	21.6	20.1	24.3	22.2	25.3	20.1
20	21.5	20.7	20.2	20.7	23.1	21.1	26.2	21.5	23.0	24.1	22.2	26.2	20.2
30	22.2	20.3	21.2	20.6	22.1	21.7	23.3	21.9	24.1	24.8	22.2	24.8	20.3
Feb. 9	26.4	19.8	24.8	21.2	22.5	22.2	21.8	20.5	23.4	21.9	22.5	26.4	19.8
19	25.2	21.2	25.2	21.4	20.8	23.6	22.4	21.1	23.9	21.4	22.6	25.2	20.8
Mar. 1	21.9	21.4	22.5	21.5	22.5	20.9	22.1	22.4	23.2	23.1	22.1	23.2	21.0
11	22.2	21.1	24.1	21.9	26.3	26.0	25.2	23.2	22.3	22.5	23.4	26.3	21.1
21	22.6	21.0	25.3	23.6	24.4	24.4	27.4	22.1	22.1	24.1	23.6	27.4	21.0
31	21.4	21.3	25.9	24.2	24.5	23.7	26.9	22.7	24.2	25.1	24.0	26.9	21.3
Apr. 10	23.7	21.5	25.3	23.6	21.5	24.0	27.2	23.7	25.5	24.3	24.0	27.2	21.4
20	23.7	22.3	25.0	25.3	23.3	24.7	27.1	24.2	24.6	26.7	24.6	27.1	22.3
30	24.0	22.5	26.3	27.1	24.3	26.1	29.4	24.3	24.6	26.8	25.5	29.4	22.5
May 10	22.2	22.4	26.7	27.4	28.1	28.2	29.4	23.4	25.0	26.1	25.9	29.4	22.2
20	22.5	21.4	28.4	24.2	27.5	28.4	28.4	24.5	24.9	27.0	25.8	28.4	21.4
30	24.1	21.5	28.3	26.6	28.1	29.2	28.6	25.7	25.1	27.3	26.4	29.2	21.5
June 9	24.6	21.5	27.5	28.1	27.0	28.4	28.0	27.8	28.1	26.9	26.8	28.4	21.5
19	24.9	22.0	27.7	28.6	27.5	29.3	28.3	29.5	27.6	28.2	27.4	29.5	22.0
29	23.7	24.4	29.4	29.0	27.6	29.6	28.2	28.8	28.4	27.9	27.7	29.6	23.7
July 9	23.4	26.5	29.5	28.2	27.7	29.5	28.9	28.7	28.0	27.7	27.9	29.5	23.4
19	24.1	27.3	29.5	30.1	27.8	30.9	29.2	28.5	28.1	28.2	28.4	30.9	24.1
29	24.8	27.3	30.0	28.5	28.2	30.8	29.4	28.7	28.5	28.5	28.5	30.8	24.8
Aug. 8	23.6	27.8	29.1	27.8	29.0	29.9	30.0	29.0	28.9	28.5	28.4	30.0	23.6
18	23.5	27.6	29.6	29.4	30.3	29.5	29.0	29.8	28.9	28.3	28.6	30.3	23.5
28	25.1	27.4	29.4	29.3	29.5	29.1	29.4	30.0	28.6	28.1	28.6	30.0	25.1
Sept. 7	25.4	27.5	29.4	29.8	29.4	28.6	28.5	29.6	28.0	28.8	28.5	29.8	25.4
17	23.8	27.7	29.0	29.7	28.6	28.3	28.3	27.6	29.0	28.9	28.1	29.7	23.8
27	24.3	27.6	28.8	29.5	28.7	29.0	28.2	27.8	28.5	29.1	28.2	29.5	24.3
Oct. 7	23.6	27.6	26.8	28.3	28.3	27.9	27.2	27.2	28.3	28.6	27.4	28.6	23.6
17	23.6	26.8	26.6	27.1	27.4	26.8	27.5	26.7	28.2	28.8	27.0	28.8	23.6
27	22.3	24.0	26.9	26.9	26.5	25.3	28.0	27.5	27.9	29.4	26.5	29.4	22.3
Nov. 6	22.5	24.6	26.8	26.8	25.7	24.2	27.0	23.4	27.7	26.5	25.4	27.7	22.5
16	22.2	25.1	26.0	25.0	25.3	27.4	25.0	23.4	27.4	26.0	25.3	27.4	22.2
26	21.6	24.4	23.8	25.7	24.4	26.3	23.0	23.0	26.2	26.4	24.5	26.4	21.6
Dec. 6	21.2	24.3	24.0	23.8	23.5	27.9	22.8	22.4	24.9	23.8	23.8	27.9	21.2
16	21.8	21.8	22.0	23.1	24.4	24.8	23.5	20.9	24.7	24.4	23.2	24.8	20.9
31	21.5	22.0	22.5	21.1	25.1	24.9	19.6	20.4	25.3	24.3	22.6	25.3	19.6

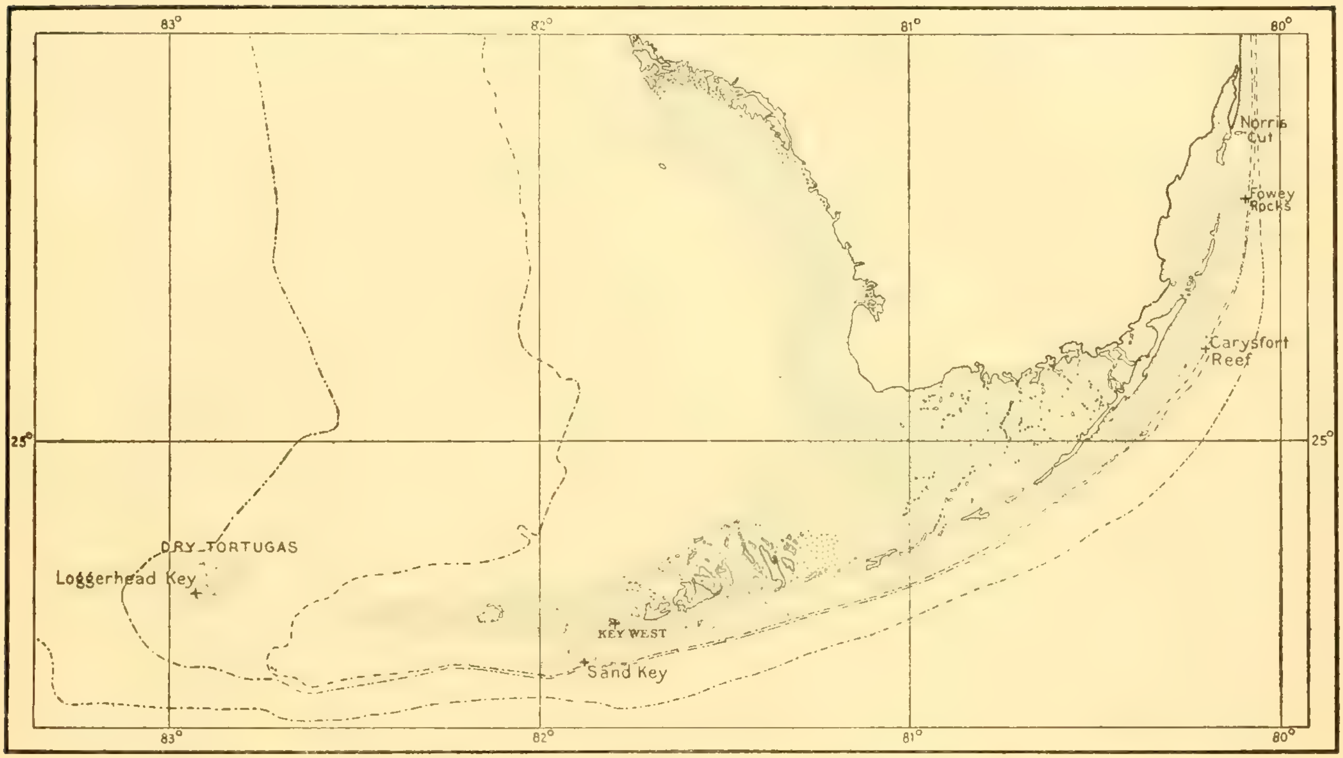

Fig. 8.—Map of Florida coral-reef tract, showing position of Dry Tortugas, Key West (Sand Key Lighthouse), Carysfort Lighthouse, and Fowey Rocks Lighthouse.

SALINITY AND TEMPERATURE NEAR BERMUDA, THE BAHAMAS, AND FLORIDA.

(For the position of the stations, see figure 9, page 339 the maximum depths at a station under 1,000 meters indicates bottom; if the maximum is over 1,000 meters, bottom may not have been touched.)

The data for the following table were obtained during the cruise of the U. S. Coast and Geodetic Survey Steamer *Bache*, while under the command of Capt. C. C. Yates, in February and March, 1914; the tabulations were made by Mr. W. W. Welsh, naturalist of the ship; and Dr. H. F. Moore, of the U. S. Bureau of Fisheries, has furnished the copy for publication in this paper. The bearing of the information on the bathymetric distribution of reef corals is discussed on pages 321, 322.

Salinity and temperature near Bermuda, the Bahamas, and Florida, U. S. Coast and Geodetic Survey Steamer Bache, 1914.

Date.	Station No.	Lat. N.	Long. W.	Depth.	Salinity.	Temp.
		° ′	° ′	*meters.*	*p. ct.*	°C.
1914						
Feb. 4	10174	32 28	67 41	Surface.	36.44	18.9
5	10175	32 28	66 28	Surface.	36.38	18.9
				20	36.38	18.9
				100	36.36	18.9
				200	36.45	18.9
5	10176	32 30	65 48	Surface.	36.44	19.2
6	10177	32 32	65 12	Surface.	36.42	19.1
				20	36.40	18.95
				100	36.44	18.95
				200	36.42	18.97
17–18	10178	32 20	64 21	Surface.	36.42	18.8
18	10179	32 12	64 42	Surface.	36.40	18.64
				20	36.44	18.40
				100	36.44	18.50
				200	36.42	18.52
18–19	10180	31 52	65 14	Surface.	. .	18.1
19	10181	31 01	65 58	Surface.	36.42	19.37
				20	. . .	19.28
				100	36.42	18.78
				200	36.44	18.89
19–20	10182	30 27	66 05	Surface.	36.56	20.12
Mar. 3	10196	25 27	77 16	Surface.	36.58	22.83
				20	. . .	22.84
				100	36.56	22.82
				500	35.64	12.93
13	10197	24 18	81 50	Surface.	36.06	20.78
				20	36.02	20.89
				60	36.08	20.59
				100	36	15.56
				150	35.66	13.39
				200	35.30	11.03
13	10198	23 59	81 50	Surface.	36.11	23.35
				20	36.11	23.06
				100	. . .	20.34
				200	.	13.98
				400	. .	10.36
				900	34.90	7
14	10199	23 13	81 50	Surface.	35.97	24.34
				20	36	24.6
				100	36.06	. . .
				200	36.53	23.31
				400	36.17	15.93
				600	35.28	11.24
				1,200	34.92	5.03
18	10200	23 32	81 48	Surface.	35.93	24.78
				20	35.93	24.72
				100	36.26	24.45
				200	36.58	22.34
				400	35.66	13.51
				600	35.03	9.1
				1,000	34.87	8.31
				1,400	. . . .	4.36
19	10201	23 47	81 47	Surface.	36.08	23.61
				400	. . .	18.37
				600	. . . .	13.45
				1,700	34.94	. .
1914						
Mar. 19	10202	25 34	79 24	Surface.	36.17	23.35
				20	. . . . .	23.30
				100	36.26	23.23
				200	36.67	21.82
				300	36.44	18.71
				400	36.26	16.63
				500	35.81	14.15
				700	35.53	12.17
20	10203	25 34	79 42	Surface.	36.08	24.03
				20	. . . . .	24.03
				100	36.26	23.25
				200	36.53	20.17
				300	35.99	15.95
				400	35.84	14.42
				800	34.85	6.16
20	10204	25 33	80 03	Surface.	36.17	21.75
				20	36.20	21.83
				100	36.17	21.07
				150	35.30	10.72
20	10205	27 05	79 52	Surface.	36.02	23.6
				20	36.08	22.88
				60	36.22	22.48
				100	36.04	19.19
				175	35.43	12.25
				250	34.85	6.90
21	10206	27 17	79 40	Surface.	36.09	23.75
				20	36.11	23.4
				100	36.26	23.4
				200	36.55	20.13
				300	35.82	14.71
				400	35.10	9.68
				500	. . . .	8.53
				700	34.85	5.70
21	10207	27 32	79 21	Surface.	36.17	23.7
				20	36.17	23.6
				100	36.20	23.3
				200	36.56	19.93
				300	36.38	17.61
				400	36.08	15.78
				500	35.79	13.90
21	10208	27 46	78 46	Surface.	36.42	22.8
				20	36.44	22.42
				100	36.51	. . . . .
				200	36.53	19.91
				300	36.42	18.78
				500	36.18	16.39
				700	35.37	10.88
				800	35.03	8.26
Mar. 22	10209	27 57	78 15	Surface.	36.44	22.23
				20	36.45	21.52
				100	36.49	20.65
				200	36.49	18.57
				400	36.11	16.11
				500	35.97	. . . . .
				700	35.26	10.08
				800	. . . . .	7.41
				900	35.01	5.98

Salinity and temperature near Bermuda, the Bahamas, and Florida, U. S. Coast and Geodetic Survey Steamer Bache, 1914—Continued.

Date.	Station No.	Lat. N.	Long. W.	Depth.	Salin-ity.	Temp.	Date.	Station No.	Lat. N.	Long. W.	Depth.	Salin-ity.	Temp.
1914		° ′	° ′	*meters.*	*p. ct.*	°*C.*	1914		° ′	° ′	*meters.*	*p. ct.*	°*C.*
Mar. 22	10210	27 59	77 25	Surface.	36.42	21.78	Mar. 22	10211	28 08	76 48	500	36.22	16.29
				20	36.40	21.8					700	35.73	13.38
				100	36.51	21.56					850	.....	8.57
				200	36.55	20.08					1,000	35.07	6.64
				300	36.49	17.44	23	10212	28 10	76 18	Surface.	36.60	20.75
				450	36.31	17.06					20	36.56	20.8
				600	36	.....					100	36.56	20.5
				800	....	10.29					300	36.26	17.77
				1,000	35.10	6.04					500	35.97	14.62
22	10211	28 08	76 48	Surface.	36.55	20.98					750	35.10	10.01
				20	....	21.02					1,000	35.03	5.62
				100	36.55	20.85					1,800	35.01	3.67
				300	36.42	17.81							

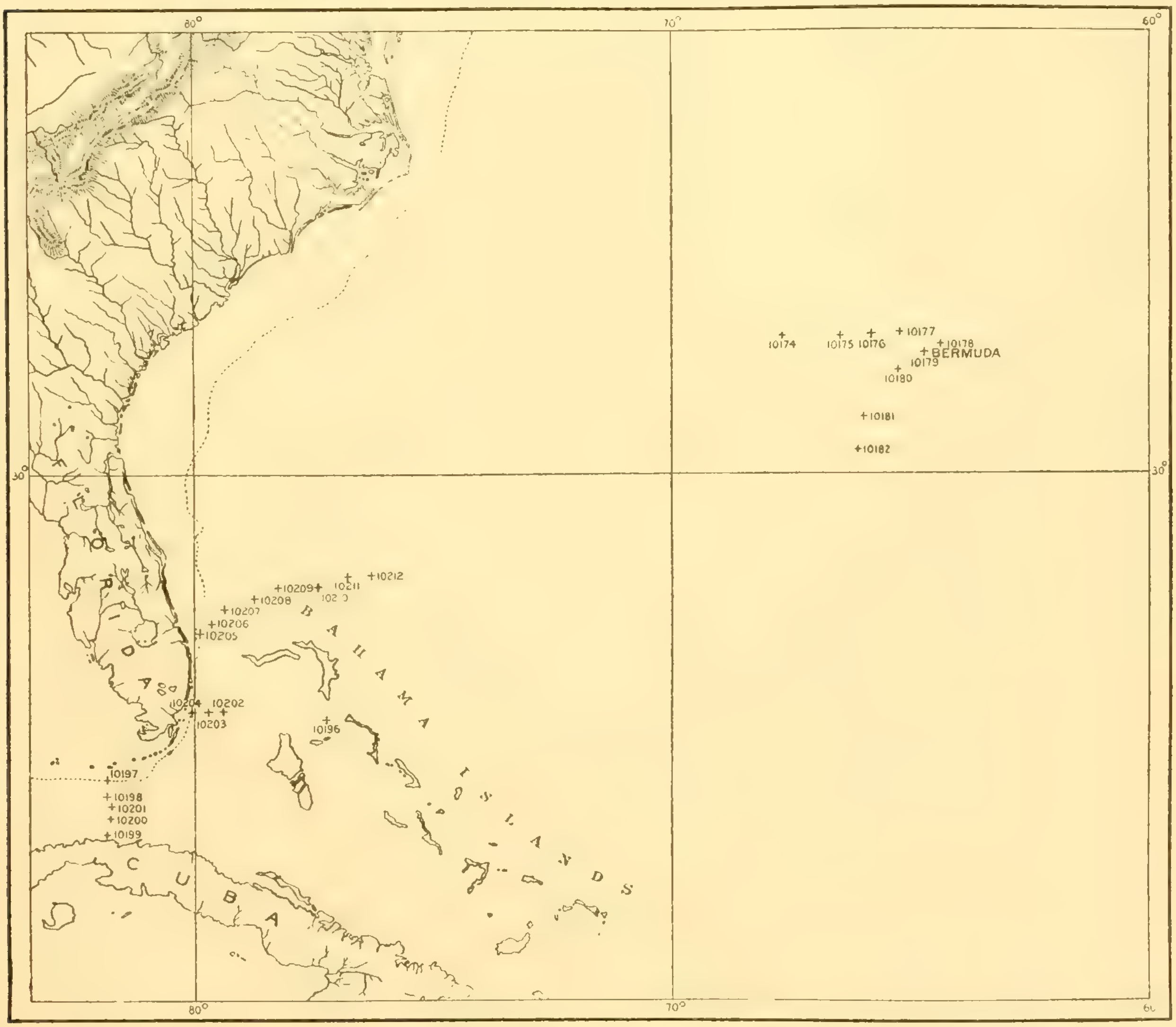

Fig. 9.—Map showing Stations at which Salinity and Temperature Records were Made by the Steamer *Bache* near Bermuda, the Bahamas, and Florida

THE GORGONACEÆ AS A FACTOR IN THE FORMATION OF CORAL REEFS

By L. R. Cary
Department of Biology, Princeton University

Six plates

THE GORGONACEÆ AS A FACTOR IN THE FORMATION OF CORAL REEFS.

By L. R. Cary.

INTRODUCTION.

An important constituent of the limestone of coral reefs is the calcium carbonate secreted in the skeletal structures of Anthozoa and marine calcareous algæ. Representatives of the Hydrozoa were important reef-formers in past geological epochs, but in the formation of modern reefs they constitute a minor factor. Representatives of the Anthozoa—the stony and flexible corals—are among animals the only important contributing agents in the formation of the modern reefs.

The formerly prevailing idea as to the relative importance of animal and vegetable organisms in reef formation underwent extensive change as a result of the borings at the island of Funafuti, in the Ellice Islands, made under the direction of a committee of the Royal Society of London. The examination of the cores from these borings showed that in this particular region calcareous algæ of the genus *Halimeda* had been a very active agent in the accumulation of limestone. At the bottom of the lagoon there was a depth of somewhat more than 100 feet where the deposit was made up almost entirely of the remains of this form and the skeletons of Foraminifera. In the body of the reef, and at a greater depth at the bottom of the lagoon, the abundance of material formed by the activity of these algæ was very much less than in the former boring, so that, when the entire deposit of limestone is considered, the algæ are a much less important factor than is indicated by the character of the surface deposits within the lagoon. Foraminifera and "other organisms" were found to make up a considerable portion of the limestone brought up in the course of both borings.

Of the animals which (by their power of secreting calcium carbonate from sea-water) have been designated as reef-builders the Madreporaria, among modern forms, have attracted the most attention on account of the character of their skeleton. In all these animals the skeletal growth is apparent from the early development of the colony, and after the death of the polyps the skeleton retains for a long time those structural characteristics which distinguish the different species. Of the Alcyonaria, those types alone which secrete a massive skeleton, *i. e.*, one in which the spicules are fused to a solid mass, have received adequate consideration as contributing to reef formation. Many of the other Alcyonaceæ, which when alive form much larger colonies than those last-mentioned, leave no conspicuous remains, as the skeletal spicules are scattered soon after the death of that portion of the colony by which they were secreted.

On many reefs, *e. g.*, on portions of the Great Barrier Reef of Australia (Saville-Kent) and those of the Philippine Islands,[1] the Alcyonaceæ, whose skeletons consist of loose spicules, constitute a large part of the lime-secreting fauna. Their spicules are, however, so small and so easily broken apart that they have not been recognized in samples of the coral rock from these reefs. Saville-Kent, in writing of the "Alcyonarian reefs" of Australia, states that the amount of lime secreted as spicules by these forms must be large, but is not available for addition to the reef until the death of the colony and the disintegration of the cœnenchyma have set free the spicules. Although a considerable portion of his work is devoted to a consideration of the rate at which reef-formation takes place, he dismisses the matter of the contribution of lime by the Alcyonaria with the above statement.

In the Florida-Antillean region the most abundant representatives of the Alcyonaria are the plume-like Gorgonaceæ; but in this region the only forms which have a dense lime-bearing axial skeleton belong to the family Isidæ. All other forms have free spicules which are scattered on the disintegration of the living tissues.

On all the coral reefs of the Florida-Antillean region which the writer has visited, the area occupied by living coral is so small, in proportion to the entire reef area, that it has seemed to him beyond question that some other organisms must be more actively participating in the laying down of lime on the reef. In many localities the Gorgonians growing on the shallow portions of the reef—down to 6 fathoms—constitute by far the largest part, either numerically or in bulk, of the organisms permanently attached to a given reef area. Besides, the presence of Gorgonian spicules in nearly all bottom samples from the reef, and even in the soft mud from the channels between the reefs, indicates that they remain in a recognizable condition for a considerable time after the disintegration of the colony and might be incorporated in the reef limestones before they had undergone marked erosion. On the basis of the two last-mentioned facts it seemed to me evident that the Gorgonians must be an important contributing factor in reef limestone formation. The greater part of the time during a stay of six weeks at the Marine Laboratory of the Carnegie Institution of Washington at Dry Tortugas, Florida, during the summer of 1914, was therefore devoted to a study of this problem.

Three factors must be taken into consideration in order to determine the amount of material contributed to reef-formation by the Gorgonians during any given time: First, the amount of lime held as spicules in the tissues of these colonies; second, the number of Gorgonians present on any reef area; and third, the number of colonies which will set free their spicules on account of the death and subsequent disintegration of their cœnenchyma.

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[1]Based upon a private communication from Mr. S. F. Light, instructor in biology at the University of the Philippines, Manila.

SPICULE CONTENT.

In the determination of the amount of spicules in any colony, the following procedure was carried out. The colony was removed from the reef without injury to any portion except the expanded base. As in most instances the expanded basal portion of the colony inclosed a mass of calcareous material which could not be easily separated without the loss of some of the Gorgonian tissues, each colony was cut off close to the base and the base was discarded. The colony was weighed while still wet, cut into small pieces, and the living tissues destroyed by treatment with caustic soda. As a practical working method, it was found most satisfactory to treat the fragments of a colony with a cold 25 per cent solution of the caustic and to remove the pieces of the chitinous axial skeleton rather than to take the time to destroy the latter by prolonged boiling. When the organic material of the cœnenchyma had been destroyed by the caustic solution and sufficient time had been allowed for all of the spicules to settle to the bottom of the jar, the liquid was decanted off and the spicules washed repeatedly in rain-water until no trace of organic debris could be detected in the wash-water. After the last washing, the spicules were collected on a weighed filter, the filter and spicules were dried for 12 hours in a water bath kept at 100° C. and carefully weighed after cooling in a desiccator to room temperature.

The reason for making these determinations upon material weighed in a moist condition rather than after drying, which would frequently have been more convenient, was that by the use of the first-mentioned method, the results showed the proportion of spicules to the fresh weight of any colony immediately after it had been collected. This basis of computation made it possible to secure a tolerably accurate estimate of the spicule content of any mass of Gorgonians by simply separating the several species represented and determining the weight of each one.

In practice, the method worked out satisfactorily except for *Gorgonia acerosa*. Out of 14 analyses attempted on this form, only 3 could be completed. In all of the other attempts, as soon as the material was subjected to the action of the caustic solution, a thick sirupy mass was formed, in which spicules remained suspended for an indefinite time. Even after the dilution of such a mass with ten times the original volume of water, the spicules were held in suspension, nor could the liquid be forced through a suction filter to separate the spicules. After a few analyses of this form had been attempted, and the results compared, it was found possible to recognize on the reef those individuals which could be successfully disintegrated by the caustic. Presumably this difference in reaction is dependent upon a physiological (metabolic) condition of the Gorgonian colony, but of all those studied it was observed in this species alone.

Previous studies on the ecology of the Gorgonians on the reefs about the Tortugas islands had shown that at least nine-tenths of the bulk of these animals on any reef area are made up of individuals of not more than 12

TABLE 1.—*Percentage by weight of spicules in Gorgonian colonies.*

Species.	No. of specimen.	Fresh weight of colony.	Weight of spicules.	Spicules.	Average spicules.
		grams.	*grams.*	*p. ct.*	*p. ct.*
	1	51.00	14.084	27.54	
	2	79.00	19.184	24.28	
Briareum asbestinum	3	246.00	84.198	31.98	26.66
	4	46.00	11.952	25.98	
	5	48.00	11.382	23.59	
	1	3.25	0.866	26.64	
	2	46.00	16.335	35.51	
Eunicea rousseaui	3	78.50	27.370	34.86	35.60
	4	196.00	87.400	44.08	
	5	338.00	121.588	38.93	
	1	33.50	7.706	23.00	
	2	114.00	23.487	20.93	
Eunicea crassa	3	121.00	29.487	24.36	22.36
	4	56.00	10.371	18.51	
	5	48.50	12.128	25.00	
	1	13.00	5.057	38.90	
	2	23.00	5.486	23.85	
Plexaura flexuosa	3	191.00	63.465	33.22	30.66
	4	145.00	40.164	27.67	
	5	45.00	13.300	29.77	
	1	84.00	20.298	24.57	
	2	33.00	9.820	29.76	
Plexaura homomalla	3	320.00	85.696	26.78	27.41
	4	113.00	28.916	25.59	
	5	186.00	56.358	30.35	
	1	91.00	22.349	24.56	
	2	291.00	58.200	20.00	
Pseudoplexaura crassa....	3	233.00	45.829	19.66	21.48
	4	569.00	105.000	18.49	
	5	1944.00	539.000	27.72	
	1	49.75	17.309	34.79	
	2	83.00	30.538	36.79	
Plexaurella dichotoma.	3	201.00	67.707	33.68	35.86
	4	39.00	13.993	35.72	
	5	15.50	5.940	38.32	
	1	250.50	61.998	24.75	
	2	31.00	7.699	24.83	
Plexaurella sp............	3	28.00	7.264	25.87	24.92
	4	129.00	31.367	24.31	
	5	14.00	3.498	24.82	
	1	29.00	6.186	21.27	
	2	50.00	10.947	21.89	
Gorgonia flabellum	3	117.50	27.273	23.21	22.33
	4	67.00	12.491	18.63	
	5	2.70	0.855	31.66	
	1	12.50	2.219	17.75	
Gorgonia acerosa..	2	50.50	13.513	26.76	19.75
	3	68.00	10.719	15.75	
	1	10.00	3.359	33.59	
	2	16.00	4.967	31.04	
Gorgonia citrina	3	23.00	9.252	39.24	35.05
	4	22.00	8.104	36.26	
	5	25.00	8.785	35.14	
	1	78.00	17.942	22.97	
	2	18.00	4.926	26.25	
Xiphigorgia anceps	3	178.00	45.050	25.23	25.83
	4	11.00	3.258	29.61	
	5	14.50	3.642	25.11	
Average percentage of spicule content for the 12 species					27.40

species. The spicule determinations were consequently restricted to these more abundant forms. In selecting material for the determination, colonies of various sizes were taken, in order to have the final averages cover as wide a series of the different ages of the colonies as was possible without using the larger specimens of any species. The results of the determination on five[1] specimens of the several species are shown in table 1.

As would be expected, those forms having the thickest layer of cœnenchyma about the horny axis showed the highest percentage of spicules. Those also in which the cœnenchyma is most dense, *e. g.*, *Eunecia rousseaui*, have a much higher spicule content than others in which the cœnenchyma is soft—for example, *Pseudoplexaura crassa*, in which the entodermal canals and the polyps are relatively very large. This last-mentioned difference becomes much more evident when the dry weight of the colonies is taken as the basis for computing the percentage of spicules. In *Eunecia rousseaui* the proportion between the fresh weight and the dry weight was as 100 to 85, while in *Pseudoplexaura crassa* it was as 100 to 55. The same characteristic was especially noticeable in *Briareum*, in which (although the central axis consists entirely of interlaced spicules) the spicule content was smaller than in several other forms and, indeed, less than the average for the entire 12 species on which determinations were made. That the size of the spicules is also an important factor is shown by the fact that while all members of the genus *Gorgonia* have a relatively thin cœnenchyma, the presence of very small, densely packed spicules brings the spicule content well up to that shown by other forms.

The data contained in table 1 were obtained primarily to give a basis from which the amount of spicules in any mass of Gorgonians could be computed without the necessity of making separate determinations on such large amounts of material as would necessarily be handled in an extended survey of the reefs. In order, however, to have a more reliable check for these computations, a series of determinations of the spicule content of the Gorgonians were made from a number of squares, each with sides a yard in length. The results of these determinations are shown in table 2.

In securing the material for these determinations, a square frame made from iron pipe, with an area of one square yard, was thrown to the bottom without any previous observation of the number of Gorgonians there present. After their removal, the colonies were sorted, those of any one species being kept together, and determination was made of the total amount of spicules for each kind. For these observations the only selection made was that in practically all instances the specimen was gathered on portions of the reefs where the water was sufficiently shallow to permit one to wade.

Squares 1 to 6 were on the shallow reef west of Loggerhead Key and were scattered along a line some 2 miles in length. Squares 7 to 14 were taken along a line about 0.5 mile in length on the east side of Loggerhead Key. Square 15 was on a reef about 3.5 miles east of Loggerhead Key, where the Gorgonian fauna was very sparse, but was included to make the

[1]Only three determinations were carried out on *Gorgonia acerosa*, for the reasons previously mentioned.

average truly representative of the condition throughout the reefs within this group of islands. Squares 16 to 18 were on the outer, exposed side of a long reef which slopes rapidly into the deep water of the Rebecca Shoal channel, and is the most exposed location where collections were made in shallow water. Squares 19 and 20 were on a very shallow protected reef where wave action and currents are at their minimum for this region. Altogether, the conditions represented by the areas chosen for these collections fairly represent those under which the Gorgonians are growing on all the reefs about the Tortugas groups. Since all of the species included in these determinations occur on the reefs in depths from just below low-tide mark to 6 fathoms, the fact that the collections were made in shallow water does not introduce any unusual condition which could invalidate the results secured.

TABLE 2.—*Weight of Gorgonians taken from a square yard on the crests of shallow reefs about Dry Tortugas, and the amount of spicules for each square.*

Square.	Location of square.	Weight of Gorgonian colonies.	Weight of spicules.
		lbs.	*lbs.*
No. 1	Shallow reef west of light-house on Loggerhead Key	9.25	2.514
2	Outer shallow reef northwest from light-house	16.75	4.92
3	West Reef opposite light-house wharf	7.50	1.875
4	West Reef opposite north end of Loggerhead Key	4.25	1.19
5	West Reef north from laboratory wharf	11.75	2.89
6	West Reef north by east from Loggerhead Key	8.50	2.45
7	East Reef southeast from light-house, sandy bottom with scattered coral heads	25.00	6.94
8	East Reef south from light-house, rough bottom	3.25	0.84
9	East Reef south by west from light-house, near shore	5.00	1.50
10	East Reef, very shallow portion southeast from light-house, on north side of reef	3.00	0.91
11	East Reef, central part of shallow area	4.75	1.43
12	East Reef, south side of shallow area	7.50	2.25
13	East Reef northeast from light-house; in 1 fathom	20.50	[1]4.10
14	East Reef, east from laboratory	2.00	0.56
15	Reef southwest of Bird Key	1.50	0.45
16	Outer edge of Bush Key reef, at north end	5.00	1.22
17	Outer edge of Bush Key reef, near entrance to 3-foot channel	7.50	1.875
18	Outer edge Bush Key reef, southeast from Fort Jefferson	3.75	1.125
19	On shallow reef northwest from Fort Jefferson	4.25	1.180
20	On same reef, west from Fort Jefferson	6.25	1.650
Average weight of spicules from the 20 square yards			2.1225

[1]The Gorgonian fauna of this square was made up entirely of the two species *Gorgonia flabellum* and *G. acerosa*, so that the weight of spicules in proportion to the weight of the mass of colonies is decidedly lower than the average for other squares.

The very marked differences in abundance of the Gorgonian fauna seen when square 7 is compared with square 15 may be found over any large reef area. In some particular locations, comparatively large areas, several hundred yards in extent, are found where the Gorgonians are more abundant than on square 7, although every reef has areas where nothing but bare limestone or coral sand occurs. As a general feature of most of the shallow reefs within the Tortugas group, the Gorgonians are, however, the most prominent feature of the topography, usually outnumbering all other organisms of any noticeable size. The locations of the squares mentioned above are shown on the map (plate 100).

DISTRIBUTION OF GORGONIAN COLONIES ON THE REEFS ABOUT TORTUGAS.

In order to obtain a reliable estimate of the number of Gorgonian colonies occurring on a considerable area of one of the typical reefs, a series of counts (made by the use of the square-yard frame of iron pipe) were made along a line running north-northwest from the laboratory wharf on Loggerhead Key, extending across the west reef from its inner edge, over the shallow crest and down its outer slope to a depth of about 6 fathoms. On the shallower portion of the reef the counts were made about 40 feet apart. Farther out, where the increasing depth of water made it impossible to identify with certainty any of the species except *Gorgonia flabellum* and *Gorgonia acerosa*, the counts were made about 60 feet apart until the 6-fathom line was reached. Here the counts were discontinued, as dredgings had shown that beyond this point the Gorgonian fauna is comparatively scanty and for the most part made up of different forms from those occurring on the reefs in shallow water. The results of this series of counts is shown in table 3.

TABLE 3.—*Gorgonians counted on line across outer reef west of Loggerhead Key.*

1.	Gorgonia acerosa	1
	Plexaura flexuosa	2
	Eunecia crassa	2
2.	No Gorgonians.	
3.	Plexaurella dichotoma	1
	Gorgonia flabellum	1
4.	No Gorgonians.	
5.	Do.	
6.	Gorgonia flabellum	1
	acerosa	1
	Plexaura flexuosa	1
	Eunecia crassa	2
7.	Gorgonia acerosa	1
	Plexaura flexuosa	1
8.	Gorgonia flabellum	2
	Plexaura flexuosa	4
	Eunecia crassa	4
	rousseaui	2
	sp	1
	Briareum sp	2
9.	Gorgonia flabellum	2
	Plexaura flexuosa	2
	Eunecia crassa	1
10.	Gorgonia flabellum	2
	acerosa	2
	Plexaura flexuosa	2
	Briareum asbestum	1
	Pseudoplexaura crassa	1
	Eunecia rousseaui	1
	crassa	1
11.	Plexaura flexuosa	1
	Eunecia crassa	5
	rousseaui	1
12.	Plexaura flexuosa	4
	Gorgonia flabellum	1
	Plexaurella dichotoma	2
	sp	1
12.	Eunecia rousseaui	1
	crassa	2
13.	Gorgonia flabellum	1
	Plexaura flexuosa	3
	Eunecia crassa	4
	rousseaui	2
14.	Gorgonia acerosa	1
	flabellum	1
	Eunecia rousseaui	2
15.	Plexaura flexuosa	1
	Eunecia rousseaui	2
16.	Plexaura flexuosa	2
	Pseudoplexaura crassa	2
17.	Gorgonia flabellum	1
	Plexaurella dichotoma	1
	Eunecia crassa	2
18.	No Gorgonians.	
19.	Plexaura flexuosa	1
	Gorgonia acerosa	1
20.	Gorgonia acerosa	1
21.	No Gorgonians.	
22.	Gorgonia flabellum	2
	Plexaura flexuosa	3
	Pseudoplexaura crassa	5
	Eunecia crassa	7
23.	Gorgonia acerosa	6
	flabellum	2
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	2
24.	No Gorgonians.	
25.	Gorgonia flabellum	4
	acerosa	2
	Plexaura flexuosa	2
	Eunecia rousseaui	1
	crassa	4
26.	Gorgonia flabellum	3
	acerosa	2
27.	Gorgonia flabellum	2
28.	Gorgonia flabellum	3
	acerosa	1
	Plexaura flexuosa	1
	Pseudoplexaura crassa	1
	Eunecia crassa	6
29.	Gorgonia flabellum	2
	acerosa	1
	Plexaurella dichotoma	2
	Eunecia rousseaui	1
[1]30.	Gorgonia flabellum	2
	acerosa	1
	Other forms	4
31.	Gorgonia flabellum	2
32.	Gorgonia acerosa	2
	Other forms	4
33.	Gorgonia flabellum	2
	acerosa	1
	Other forms	3
34.	Other forms	5
35.	Gorgonia acerosa	1
36.	Gorgonia acerosa	1
	Other forms	3
37.	Other forms	2
38.	Gorgonia acerosa	3
	Other forms	2
39.	Gorgonia flabellum	3
40.	Gorgonia flabellum	2
	Other forms	4
41.	No Gorgonians.	
42.	Gorgonia acerosa	1
	Other forms	3
43.	No Gorgonians.	
44.	Gorgonia flabellum	2
45.	Gorgonia flabellum	1
	acerosa	1

[1]Beyond this point the depth of the water was too great to allow of the certain identification of any of the gorgonians except *Gorgonia flabellum* and *G. acerosa*. The number of individuals of all other species is therefore given under the caption "other forms."

Along this line, which was approximately 0.35 of a mile in length, in only 8 of the 45 counts made did the frame fall upon an area of bottom upon which no Gorgonians were growing. The largest number counted on any square yard was 17. The average for the whole 45 counts was 5.72. Counts upon a number of other reefs in different parts of the group show that the proportion of squares on which no Gorgonians were found was considerably higher along this line than that obtained by averaging all of the counts. The average of one empty square to each 5.6 of those counted as found in the series recorded in table 3 is almost twice as great as the average for all the counts made on the reefs about Tortugas, which was one empty square in each 10.03. Besides the counts along this line, other series were made on nearly all of the shallow reefs in the Tortugas group. The most important were the following (Plate 100):

(1)[1] A line about 2.5 miles in length running nearly northeast along the crest of the West Reef from opposite Loggerhead Key to the northwest channel. The average number of Gorgonian colonies for the 150 counts along this line was 8.97. In only 14 casts did the frame fall upon an area of barren bottom.

(2) A series of counts on 4 small reefs east of the northwest channel where in each instance the line of countings was extended from deep water on one side of the reef over its crest and down to deep water on the other side. The average number of Gorgonian colonies for the 30 counts made on 3 of the reefs in this locality was 10.86. In 3 casts the frame fell upon barren bottom.

(3) Along a line running north-northwest from the Pulaski Shoal buoy, from the edge of the Rebecca Shoal channel over the reef and to deep water on its inner side, 25 counts were made. The average number of Gorgonian colonies for 20 counts along this line was 7.62, while in only one of the casts did the frame fall upon an area of barren bottom.

(4) In a series of counts along the outer side of Long and Bush Keys, starting from the northwestern end of the former, extending along the northeast channel, and then down the outer face of the long reef to the southward, the average number of Gorgonian colonies found in 40 counts was 13.27. The number of squares upon which no Gorgonians occurred was 7. This series of counts extended over an area upon which there was a very unusual destruction of Gorgonians during the severe hurricane that had its center in the Tortugas region on October 17, 1910. The unusually large number of colonies found is probably due to the fact that the normal conditions for the Gorgonian fauna have not as yet been re-established. Nearly all of the colonies occurring on this section of the reef were of small size, so that the spicule content of the Gorgonians upon any square yard would be below the average found for the determination based upon the counts from other reefs.

[1]Details of the counts along these lines are given in tables 10 to 14 in an appendix to this paper.

(5) In a series of counts on a line extending along the axis of White Shoal, the average number of colonies to the square yard was 5.86 for 35 counts. On 5 squares no Gorgonians were found. In this series the conditions on the southern end of the shoals were exceptional and were again due to the hurricane of October 1910. At that time the larger portion of this end of the shoal was covered by a mass of broken coral and shell to a depth of 4 feet on the highest part of the reef. In January 1911 an area, roughly 2 acres in extent, was laid bare at low tide. Across the entire crest of the reef the water was 2 to 4 feet shallower than before the hurricane. In the course of the next 18 months all of this loose material had been washed away, so that the shoal was again back to its former level, but absolutely bare of Gorgonians. Within the interval since July 1912 a "set" of Gorgonians, almost entirely of a single species, *Gorgonia acerosa*, has become established over this area, so that a determination of the colonies on 75 square yards (including 15 in the series along the axis of the reef) gave an average of 4 to the square yard. On the northern three-fifths of this shoal, the Gorgonian fauna had not suffered any extensive injury from the hurricane and was of the same character as that found generally on the other reefs.

TABLE 4.—*Average weight of a single Gorgonian colony.*

Species.	Average weight.	Species.	Average weight.
	lbs.		*lbs.*
Briareum asbestum....	2.00	Plexaurella dichotoma.....	0.75
Eunecia rousseaui.....	1.00	sp............	0.75
crassa.....	0.30	Gorgonia flabellum......	1.00
Plexaura flexuosa......	1.00	acerosa.........	3.00
Pseudoplexaura crassa....	2.50	citrina..........	0.50
Plexaura homamalla..	1.00	Xiphigorgia anceps.......	0.50

As a basis for the computation of the weight of Gorgonian colonies occurring on any square yard of reef area, the figures given in table 4 show the weight of a colony of the several species listed as determined by averaging the weight of 20 colonies of medium size.

Computed upon this basis, the average weight of the Gorgonian colonies collected on the squares along the reef west of Loggerhead Key is 7.32 pounds. Estimating by the average percentage of spicules (27.40 per cent) as determined for the 11 species as shown in table 1, the average spicule content for each square yard is 2 pounds. This result approaches very closely that found by actual determination of spicule content of the Gorgonian colonies on 20 square yards as given in table 2. Since the number of colonies per square yard was in this series the smallest found in the counts on any reef, the spicule content when estimated upon the same basis would be considerably greater for many of the other reefs than the amount determined by actual analysis as given in table 2.

Since the foregoing statement was written, additional data upon this question, secured during the summer of 1914, have shown that the above estimate is far below the average over the whole reef area.

The addition to the equipment of the laboratory of a "Dunn diving hood," by the use of which the study of any bottom in less than 30 feet of water is made practicable, has made it possible to secure extensive collections of the Alcyonarian fauna from the deeper reefs. In many instances the surface of the deeper reefs is covered with a dense shrub-like growth of Gorgonians of an average height of at least 3 feet. Since the surface of all of the reefs is very irregular and the Gorgonian colonies are usually attached to the higher points of the reef, many of them would reach above the level of one's shoulders as he was walking about over the reef. In general the bulk of the colonies of the most common species of Gorgonians was about twice as great as that determined for the same species from specimens collected on the shallow water reefs. The average weight of the colonies of a number of these forms taken from a reef in 18 feet of water is given in table 5.

TABLE 5.—*Weight of Gorgonian colonies from deep water.*

Species.	Weight.	Species.	Weight.
	lbs.		*lbs.*
Eunecia rousseaui...	2.20	Pseudoplexaura crassa....	4.25
crassa....	0.75	Plexaurella dichotoma....	2.00
Plexaura flexuosa..	3.50	Gorgonia flabellum.....	3.00
homomalla....	3.00	acerosa........	5.00

The proportion of spicules in the tissues of those forms for which spicule determinations were made of specimens from the deeper reefs did not differ materially from that determined for specimens from the shallow reefs, so that the estimate of 5.38 tons to the acre as the amount of spicules held in the tissues of living Gorgonian colonies on the reefs about Tortugas would be, for those reefs in more than 15 feet of water, only about half the amount actually present.

DISINTEGRATION OF GORGONIAN COLONIES AND ADDITION OF THE SPICULES TO THE REEF-BUILDING MATERIALS.

The securing of accurate data bearing upon this phase of the problem has been the most difficult part of the investigation, since there is no readily available method by which the actual destruction of colonies over any reef area can be determined when the observations on the reef are limited to a comparatively short time each year; but observations bearing directly upon this point have been accumulated in the course of studies extending over a period of five years upon the growth-rate and ecology of the Gorgonians in this region, and some investigations on the time necessary for the disintegration of the cœnenchyma of Gorgonians were carried out in the summer of 1914.

Previous observations have shown that when a Gorgonian colony is removed from its attachment on the reef and allowed to lie on the bottom, where it will be moved about by the action of tidal currents or waves (or if it is suspended upside down), death follows within a comparatively short time. The time necessary for the complete disintegration of the cœnenchyma of a colony and the consequent liberation of its spicules after it had been removed from its attachment on the reef was determined for the 12 species which make up the most important element in the Gorgonian fauna of the region. The results of these experiments are shown in table 6.

TABLE 6.—*Time necessary for the complete disintegration of the cœnenchyma of Gorgonian colonies.*

Species.	Time of disintegration.	Species.	Time of disintegration.
	hrs.		*hrs.*
Briareum asbestum	48	Plexaurella dichotoma	60
Eunecia rousseaui	96	sp.	48
crassa	68	Gorgonia flabellum	120
Plexaura flexuosa	32	acerosa	36
homomalla	24	citrina	30
Pseudoplexaura crassa	18	Xiphigorgia anceps	24

Under normal conditions on the reef, the greatest number of axial skeletons of dead colonies are found in positions which indicate that the tearing of the colony from its original attachment by wave-action is the cause of the greatest mortality. When destroyed in this manner, the spicules from any colony would be added to the limestone-forming materials on the reef within a few days, at most, from the time the colony was torn from the reef. Another active destructive agent, at least on the reefs about Tortugas, is the hydrocoralline *Millepora alcicornis*. On any reef numerous Gorgonian colonies are found, a part of the axial skeleton of which is incrusted with a growth of *Millipora*. The work of this destructive agent is particularly striking on colonies of *Gorgonia flabellum*. The axial skeleton of this species still retains its delicate lace-like pattern after it has been overgrown by the white *Millepora*. In many instances colonies are found in which the basal portion is entirely incrusted by this foreign growth, while the distal portion still bears the normal Gorgonian tissues, apparently as yet unaffected by the destruction of the cœnenchyma on the proximal portion. In all such colonies examined the disintegration of the cœnenchyma had taken place previous to the overgrowth of the axial skeleton by the *Millipora*, so that the Gorgonian spicules are set free little by little as the growth of the *Millipora* goes on. Very much the same effect is brought about by the upgrowth of incrusting Bryozoa about a colony. In this case, however, the incrusting organism grows over the surface of the cœnenchyma and the death of the latter is brought about on account of the cutting off of the supply of food and oxygen rather than by some toxic substance, as seems to be the cause of the death of the tissues in colonies overgrown by *Millepora*. The disintegration

of the tissues of the cœnenchyma takes place slowly in colonies overgrown by the incrusting Bryozoa. Usually only the proximal portion of the colony is affected, while the tissues of the distal portion retain their normal activity.

So far as can be determined from observations extending over a period of five years on the reefs about Tortugas, there is no evidence of death from old age in any of the Gorgonians. Every colony lives until it meets a violent death through the agency of storms (wave action), by being overgrown by some other organism, or by its being set free on the reef through the disintegration of the material to which it was attached. Besides the tearing loose from their place of attachment of the Gorgonian colonies, another result of wave action is that frequently an amount of loose limestone debris sufficient to cover up the colonies is brought upon a reef, causing their death by excluding food and oxygen.

Table 7.—*Percentage of dead colonies on a reef.*

Date of examination.	No. of colonies.	No. of dead skeletons.	Percentage of dead skeletons.
June 1910........	548	64	11.67
January 1911....	No complete count.	136	[1]24.80?
July 1911......	456	92	20.17
July 1912.......	456	97	21.27
September 1913..	608	82	13.26
July 1914.......	642	78	12.14
			Aver. 17.22

[1]Computed upon the basis of the count of June 1910.

The facies of the Gorgonian fauna on any reef remains practically constant except for the introduction of the unusual factor of extensive destruction of colonies as an effect of severe storms. The determination of the number of axial skeletons of dead colonies on any reef is, therefore, the only practical method of determining the death-rate of these organisms on any reef area. This method, unfortunately, has one very important source of error, in that when a colony has been torn from its place of attachment it will most often be carried for a considerable distance from its previous position and will not be included in a count of dead skeletons on a restricted area of reef. A record of the entire number of certain species of Gorgonians found on a small protected reef east of Loggerhead Key has been kept continuously for five years, and affords the most comprehensive data available on this point. The record for this reef area from 1910 to 1914 inclusive is shown in the above table.

In this record the dead skeletons for the first and last two years alone represent a normal condition. The percentage for the other years is abnormally high on account of the fact that the unusual destruction on account of the hurricane of October 1910 fell within the period of the record. On other reefs within the group, the destruction of the Gorgonian fauna at that time was in some instances complete, *e. g.*, on the southern end of White Shoal. In another locality, on the northern end of Bush Key, the amount of spicules

set free from disintegrated Gorgonian colonies was about 25 pounds to the square yard, over an area of nearly 100 square yards. On all of the reefs, except those in the most protected situations, the destruction at this time was very extensive, ranging from 15 to 100 per cent.

As heavy storms are of frequent occurrence throughout the Antillean region in late summer or early autumn, it is probable that a record extending over any considerable period of years would show that a fair estimate of the annual destruction of Gorgonians can be obtained by making an average over a period containing the date of a heavy storm. The percentage of 17.22 as the average for five years on the reef last mentioned will, therefore, represent the conditions on an unusually well-protected reef through such a period. On most of the reefs about the Tortugas group, the average destruction over a considerable period of years would unquestionably be considerably higher.

TABLE 8.—*Rate and character of the growth of certain Gorgonian colonies.*

Species of Gorgonian.	Years necessary to reach medium size.	Character of growth.
Briareum asbestum	...	Grows indefinitely from creeping stolon.
Eunecia crassa	2.5	Grows very slowly after reaching medium size.
rousseaui	3.0	Do.
Plexaura flexuosa	3.0	Do.
Pseudoplexaura crassa	2.5	Do.
Plexaura homomalla	4.0	Do.
Plexaurella dichotoma	3.0	Do.
sp.	3.0	Do.
Gorgonia flabellum	4.0	Do.
acerosa	5.0	Keeps growing indefinitely, but very slowly, after 5 years.
citrina	2.0	Grows very slowly after this time.
Xiphigorgia anceps	3.0	Do.

Since the facies of the Gorgonian fauna on these reefs is practically unchanged from year to year under average conditions, a knowledge of the growth-rate of these forms affords a basis for determining the rate at which the lime is built up as spicules in the tissues of Gorgonian colonies. Records of the growth-rate of a considerable number of specimens of several species of Gorgonians have shown that the time necessary for such colonies to reach "medium" size, such as was used in making the determinations recorded in table 4, is comparatively short for all of the different species. The results of these records are shown in table 8.

In almost all of the species studied the growth is most rapid during the second year and becomes progressively slower from that time on. In a few species, particularly in *Gorgonia acerosa*, growth takes place for an indefinite period and there seems to be no definite size for the colony as there is for most other forms.

In relation to the stability of the facies of the Gorgonian fauna on any area, it has been observed that after a period of severe destruction by storm there is always an unusually large number of young colonies present on the

reefs after the first breeding season following the cataclysm. At the end of the second year most of these colonies would have attained nearly the normal size and would have brought the amount of lime held as spicules up to the average amount.

ILLUSTRATIONS.

Plates 101 to 105 are from photographs of dried specimens of the twelve species of Gorgonians which were found to constitute the major part of the alcyonarian fauna on the reefs about Tortugas. All the figures, except Nos. 9 and 10, are of specimens rather smaller than the average size.

CONCLUSIONS NEW TO SCIENCE.

The results of this study show that over large reef areas, in the region about Tortugas at least, the Gorgonian fauna is by far the most important element contributing to the formation of reef limestones. On the basis of the data recorded in tables 2 and 3 the amount of spicules in the tissues of Gorgonian colonies would average at least 5.28 tons to the acre for all of the reefs in the Tortugas group.[1] In many restricted areas the amount is very much greater, as is shown by the bulk of the Gorgonian colonies growing in these localities, or in some instances by the amount of spicules actually set free on the reefs.

The figures given above represent only a potential contribution to reef formation but a study of the normal cycle of changes in the Gorgonian fauna of this region has shown that at least a fifth of this amount of calcium carbonate, as spicules, will be added to the reef limestones annually. There are wide fluctuations in the extent to which destruction of the Gorgonian colonies takes place in any single year, but the above estimate is well within the limits found by averaging the results obtained over a period of several years.

In many regions where representatives of the family Alcyonaceæ make up the greater portion of the Alcyonarian fauna the contribution to the reef limestone would be unquestionably greater than about the Tortugas where the family Gorgonidæ is alone represented by numerous specimens.

SUMMARY.

1. The Alcyonarian fauna of the Florida-Antillean region is composed almost entirely of representatives of the order Gorgonaceæ, in which the entire lime-bearing skeletal elements are spicules formed in the cœnenchyma. The Gorgonians are, however, very numerous on most of the shallow reefs, and the presence of their spicules in practically all bottom samples indicates that they are an important element in reef limestone formation.

2. When analyzed for percentage of spicule content of the 12 species occurring most abundantly about Tortugas, it is found that from 19.75 per

[1] See table 5.

cent (*Gorgonia acerosa*) to 35.86 per cent (*Plexaurella dichotoma*) of the fresh weight of the colonies is made up of spicules. The average spicule content for the 12 species was 27.4 per cent.

3. The fresh weight of the Gorgonian colonies growing upon a square yard from different reefs varied from 1.5 pounds to 25.0 pounds. The amount of spiculæ held in the tissues of these colonies varied from 0.45 pound to 6.94 pounds. The average weight of the spicules for the 20 determinations was 2.1225 pounds.

4. The number of colonies per square yard along a series of lines extending over a number of the reefs (see map) was as follows:

TABLE 9.

Line.	No. of squares.	Average No. of colonies.	No. of barren squares.	Line.	No. of squares.	Average No. of colonies.	No. of barren squares.
No. 1	45	5.72	8	No. 4	25	7.62	1
2	150	8.97	14	5	40	13.27	7
3	30	10.86	3	6	36	5.86	5

5. An estimate of the weight of the Gorgonian colonies from each square yard in the series of counts just mentioned, based upon the average weight of the colony for common forms (see table 4), gives an average of 2 pounds for line 1. The number of colonies to the square yard along this line was the least of any line on which counts were made. Even on the basis of this estimate, the weight of the spicules held in the tissues of living colonies would average 5.38 tons per acre.[1]

6. The cœnenchyma of all the species studied will be disintegrated, setting free the spicules, within 120 hours of the time they are broken from their attachment on the reefs (table 6).

7. There is no evidence of death from old age among Gorgonians. The most important destructive agent is wave-action, with its many effects. Incrusting organisms (*Millepora*, *Bryozoa*, etc.) are also a constant factor of considerable importance.

8. A series of records extending over 5 years for one reef shows that on an average about one-fifth of the total Gorgonian fauna is destroyed each year. (Table 7.) While the facies of the Gorgonian fauna remain practically constant approximately 1 ton of limestone, as spicules, is therefore added to the surface of each acre of reef area annually. Records of the rate of growth of the most common species of Gorgonians found in the Tortugas region have shown that nearly all of them reach medium size in from 2 to 5 years, and that growth takes place very slowly after that time. (Table 8.)

[1]See table 5.

TABLE 10.—*Details of counts along line No. 1 (see page 350 and map).*

1.	Gorgonia flabellum	1
	acerosa	2
	Plexaura flexuosa	3
	Pseudoplexaura crassa	1
	Eunecia crassa	5
2.	Gorgonia flabellum	2
	acerosa	1
	Briareum asbestum	2
	Xiphigorgia anceps	2
	Pseudoplexaura crassa	2
	Eunecia crassa	5
3.	Gorgonia flabellum	3
	Plexaura flexuosa	4
	homomalla	2
	Eunecia rousseaui	2
	crassa	3
4.	Gorgonia acerosa	1
	citrina	6
	Xiphigorgia anceps	2
	Pseudoplexaura crassa	1
5.	Plexaura flexuosa	3
	homomalla	1
	Eunecia crassa	5
6.	Gorgonia flabellum	2
	Pseudoplexaura crassa	1
	Plexaurella dichotoma	2
	Eunecia rousseaui	4
7.	Barren.	
8.	Gorgonia acerosa	3
	citrina	4
	Xiphigorgia anceps	2
10.	Barren.	
11.	Gorgonia flabellum	2
	Xiphigorgia anceps	4
	Plexaura flexuosa	1
	Pseudoplexaura crassa	1
	Plexaurella dichotoma	2
12.	Briareum asbestum	2
	Plexaurella sp.	1
	Eunecia rousseaui	2
	crassa	5
13.	Gorgonia flabellum	2
	acerosa	1
	Eunecia crassa	4
14.	Gorgonia citrina	5
	Plexaura flexuosa	1
	homomalla	1
	Pseudoplexaura crassa	1
15.	Eunecia crassa	2
16.	Gorgonia acerosa	2
	flabellum	1
	Plexaurella dichotoma	2
	Xiphigorgia anceps	2
17.	Gorgonia acerosa	2
	flabellum	4
	Plexaura flexuosa	2
18.	Gorgonia flabellum	3
	Plexaurella sp	2
	dichotoma	2
	Eunecia rousseaui	2
	crassa	4
19.	Pseudoplexaura crassa	2
	Eunecia crassa	4
20.	Plexaura flexuosa	2
	homomalla	1
	Pseudoplexaura crassa	2
	Eunecia crassa	4
21.	Gorgonia acerosa	2
	flabellum	1
	Plexaura flexuosa	4
	Pseudoplexaura crassa	2
	Xiphigorgia anceps	3
22.	Gorgonia flabellum	3
	acerosa	4
	Xiphigorgia anceps	1
	Plexaurella sp	1
	dichotoma	2
	Eunecia crassa	6
23.	Barren.	
24.	Eunecia rousseaui	2
	crassa	10
25.	Pseudoplexaura crassa	3
	Plexaura flexuosa	7
	homomalla	1
	Plexaurella dichotoma	2
	Eunecia crassa	9
26.	Gorgonia flabellum	4
	acerosa	2
	Xiphigorgia anceps	2
	Plexaura flexuosa	3
	Pseudoplexaura crassa	1
27.	Plexaura flexuosa	4
	Pseudoplexaura crassa	1
	Eunecia rousseaui	2
	crassa	11
28.	Gorgonia flabellum	4
	acerosa	1
	Plexaurella dichotoma	3
	Briareum asbestum	2
	Eunecia crassa	7
29.	Gorgonia flabellum	1
	acerosa	3
	Xiphigorgia anceps	1
	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Eunecia rousseaui	4
30.	Pseudoplexaura crassa	3
	Plexaurella dichotoma	4
	Eunecia rousseaui	2
	crassa	6
31.	Gorgonia acerosa	1
	flabellum	3
	Plexaura flexuosa	3
	Plexaurella sp	1
	Pseudoplexaura crassa	2
	Eunecia crassa	5
32.	Plexaurella dichotoma	2
	Plexaura flexuosa	3
	Pseudoplexaura crassa	1
	Eunecia rousseaui	3
	crassa	4
33.	Gorgonia flabellum	2
	Plexaura flexuosa	3
	homomalla	1
	Plexaurella dichotoma	2
	Eunecia crassa	7
34.	Barren.	
35.	Barren.	
36.	Gorgonia flabellum	2
	acerosa	3
	Xiphigorgia anceps	1
	Gorgonia citrina	4
	Eunecia rousseaui	1
37.	Gorgonia acerosa	2
	Plexaurella sp	2
	Pseudoplexaura crassa	1
	Eunecia crassa	7
38.	Plexaurella dichotoma	2
	Plexaura flexuosa	4
	Eunecia rousseaui	2
	crassa	8
39.	Gorgonia flabellum	1
	Plexaura flexuosa	3
	homomalla	1
	Pseudoplexaura crassa	2
	Eunecia crassa	5
40.	Gorgonia flabellum	1
	acerosa	1
	Plexaura flexuosa	2
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	3
41.	Plexaura flexuosa	4
	homomalla	1
	Pseudoplexaura crassa	2
42.	Gorgonia acerosa	4
	Eunecia crassa	7
43.	Gorgonia flabellum	3
	acerosa	1
	Plexaurella dichotoma	2
	Eunecia crassa	4
44.	Eunecia crassa	6
45.	Pseudoplexaura crassa	1
	Plexaurella dichotoma	2
	Eunecia rousseaui	2
	crassa	5
46.	Gorgonia acerosa	2
	flabellum	3
	Plexaura flexuosa	2
	Pseudoplexaura crassa	1
47.	Plexaura flexuosa	2
	Plexaurella sp	1
	Eunecia rousseaui	2
48.	Plexaura flexuosa	2
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	3
	Eunecia crassa	4
49.	Gorgonia acerosa	3
	Xiphigorgia anceps	1
	Eunecia rousseaui	2
50.	Gorgonia acerosa	2
	flabellum	5
	Plexaura flexuosa	7
	Plexaurella dichotoma	3
	Eunecia crassa	8
51.	Eunecia crassa	4
52.	Gorgonia acerosa	1
	Plexaura flexuosa	2
	Eunecia crassa	3
53.	Gorgonia flabellum	2
	acerosa	1
	Plexaura flexuosa	2
54.	Gorgonia acerosa	1

TABLE 10.—*Details of counts along line No. 1*—continued.

55.	Plexaura flexuosa	3
	Plexaurella dichotoma	2
	Eunecia crassa	4
56.	Pseudoplexaura crassa	2
	Plexaurella dichotoma	1
	Eunecia rousseaui	2
	crassa	4
57.	Gorgonia flabellum	2
	Xiphigorgia anceps	1
	Gorgonia citrina	3
	Eunecia crassa	4
58.	Gorgonia acerosa	1
	Plexaurella dichotoma	3
59.	Barren.	
60.	Gorgonia acerosa	1
	Plexaura flexuosa	4
62.	Gorgonia flabellum	2
	Pseudoplexaura crassa	1
	Eunecia rousseaui	2
	crassa	6
63.	Gorgonia flabellum	2
	Plexaura flexuosa	4
	Plexaurella sp	2
	Eunecia crassa	3
64.	Gorgonia flabellum	3
	acerosa	1
	Eunecia rousseaui	2
65.	Gorgonia acerosa	2
	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	4
	Eunecia crassa	5
66.	Plexaura homomalla	2
	Plexaurella dichotoma	3
	Eunecia rousseaui	2
	crassa	4
67.	Gorgonia flabellum	3
	acerosa	2
	Xiphigorgia anceps	2
	Pseudoplexaura crassa	1
68.	Gorgonia acerosa	2
	citrina	4
	Plexaurella dichotoma	4
	Eunecia crassa	3
69.	Gorgonia flabellum	3
	Eunecia crassa	4
70.	Pseudoplexaura crassa	2
	Eunecia rousseaui	2
	crassa	4
71.	Gorgonia flabellum	1
	acerosa	1
	Xiphigorgia anceps	2
	Plexaurella dichotoma	3
72.	Plexaura flexuosa	3
	homomalla	1
	Briareum sp	2
73.	Barren.	
74.	Eunecia crassa	8
75.	Gorgonia flabellum	3
	acerosa	2
	citrina	3
	Plexaurella dichotoma	4
76.	Gorgonia acerosa	1
	Xiphigorgia anceps	2
	Pseudoplexaura crassa	4
	Eunecia rousseaui	2
	crassa	5
77.	Gorgonia flabellum	2
	Plexaura flexuosa	2
	Plexaurella sp	1
	dichotoma	3
78.	Gorgonia flabellum	2
79.	Gorgonia flabellum	1
	acerosa	3
	citrina	2
	Plexaura flexuosa	2
	Eunecia rousseaui	4
80.	Gorgonia flabellum	2
	Plexaurella sp	2
	Pseudoplexaura crassa	2
	Eunecia crassa	4
81.	Plexaura flexuosa	4
	Plexaurella dichotoma	1
	Eunecia rousseaui	2
	crassa	4
82.	Gorgonia acerosa	2
	Pseudoplexaura crassa	2
83.	Plexaurella dichotoma	3
	Plexaura flexuosa	2
	homomalla	1
	Eunecia crassa	4
84.	Gorgonia flabellum	3
	acerosa	1
	Xiphigorgia anceps	4
	Plexaura flexuosa	2
85.	Gorgonia flabellum	3
	citrina	4
	Pseudoplexaura crassa	2
86.	Gorgonia flabellum	2
	acerosa	1
	Plexaura flexuosa	2
	Plexaurella dichotoma	8
	Eunecia crassa	5
87.	Eunecia rousseaui	3
	crassa	6
88.	Plexaura homomalla	2
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	6
89.	Gorgonia flabellum	3
	acerosa	2
	Xiphigorgia anceps	2
	Plexaura flexuosa	3
90.	Gorgonia acerosa	3
	Plexaurella dichotoma	7
91.	Barren.	
92.	Plexaura flexuosa	3
	homomalla	1
	Pseudoplexaura crassa	3
93.	Gorgonia flabellum	2
	citrina	5
	Plexaurella dichotoma	4
94.	Gorgonia acerosa	3
	flabellum	1
	Eunecia rousseaui	2
	crassa	5
95.	Xiphigorgia anceps	2
	Pseudoplexaura crassa	3
	Plexaurella dichotoma	7
96.	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Eunecia crassa	4
97.	Eunecia crassa	2
98.	Gorgonia flabellum	2
	acerosa	3
	Plexaura flexuosa	5
	Eunecia crassa	7
99.	Gorgonia acerosa	1
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	5
	Eunecia rousseaui	7
100.	Gorgonia flabellum	2
	Xiphigorgia anceps	3
	Plexaura flexuosa	2
	Plexaurella sp	1
	Eunecia crassa	4
101.	Plexaurella dichotoma	7
	Pseudoplexaura crassa	2
102.	Plexaurella dichotoma	4
	Eunecia rousseaui	2
	crassa	4
103.	Gorgonia flabellum	2
	acerosa	3
	Plexaura flexuosa	3
	Plexaurella sp	2
	Eunecia crassa	4
104.	Gorgonia acerosa	2
	Plexaurella dichotoma	5
105.	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	4
106.	Gorgonia flabellum	2
	Xiphigorgia anceps	2
	Eunecia rousseaui	1
	crassa	4
107.	Gorgonia flabellum	2
	acerosa	1
	citrina	4
	Plexaurella dichotoma	5
108.	Barren.	
109.	Barren.	
110.	Plexaura flexuosa	4
	homomalla	2
	Plexaurella dichotoma	5
	Eunecia crassa	5
111.	Gorgonia flabellum	2
	acerosa	2
	Xiphigorgia anceps	2
	Pseudoplexaura crassa	4
	Eunecia rousseaui	1
	crassa	5
112.	Gorgonia flabellum	1
	Xiphigorgia anceps	2
	Plexaura flexuosa	2
	Plexaurella dichotoma	5
	Eunecia crassa	4
113.	Gorgonia flabellum	2
	citrina	5
	Pseudoplexaura crassa	3

Table 10.—*Details of counts along line No. 1*—continued.

114.	Gorgonia acerosa	3
	Xiphigorgia anceps	4
	Plexaura homomalla	2
	Briareum asbestum	2
115.	Xiphigorgia anceps	3
	Pseudoplexaura crassa	3
	Plexaurella dichotoma	5
	Briareum asbestum	2
116.	Gorgonia citrina	4
	Xiphigorgia anceps	3
	Plexaura homomalla	1
	Eunecia rousseaui	1
	crassa	3
117.	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	5
	Briareum asbestum	2
118.	Gorgonia flabellum	3
	Plexaurella sp	1
119.	Gorgonia flabellum	2
	acerosa	2
	Xiphigorgia anceps	3
	Plexaurella dichotoma	5
120.	Xiphigorgia anceps	2
	Plexaura flexuosa	2
	Pseudoplexaura crassa	3
	Eunecia rousseaui	2
	crassa	4
121.	Plexaura homomalla	2
	Plexaurella dichotoma	6
122.	Pseudoplexaura crassa	2
	Plexaurella dichotoma	4
	Eunecia crassa	4
123.	Gorgonia flabellum	2
	acerosa	2
	Xiphigorgia anceps	3
	Briareum asbestum	2
125.	Gorgonia citrina	5
	Xiphigorgia anceps	2
	Plexaura flexuosa	4
	Plexaurella sp	2
	dichotoma	5
126.	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	7
	Briareum asbestum	2
127.	Gorgonia flabellum	2
	citrina	4
	Xiphigorgia anceps	3
	Plexaurella dichotoma	4
130.	Barren.	
131.	Barren.	
132.	Barren.	
133.	Xiphigorgia anceps	4
	Pseudoplexaura crassa	3
	Briareum asbestum	2
134.	Gorgonia flabellum	3
	acerosa	4
	Plexaurella dichotoma	6
135.	Xiphigorgia anceps	3
	Plexaura flexuosa	2
	homomalla	1
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	4
136.	Gorgonia flabellum	3
	acerosa	2
137.	Gorgonia flabellum	2
	Xiphigorgia anceps	4
	Plexaurella dichotoma	4
	Eunecia crassa	2
138.	Plexaura flexuosa	3
	homomalla	1
	Briareum asbestum	4
139.	Gorgonia citrina	4
	Xiphigorgia anceps	2
	Pseudoplexaura crassa	4
140.	Gorgonia flabellum	3
	Plexaurella dichotoma	5
141.	Gorgonia flabellum	2
	acerosa	3
	Pseudoplexaura crassa	3
142.	Barren.	
143.	Plexaura flexuosa	4
	Plexaurella sp	2
	dichotoma	5
	Briareum asbestum	2
144.	Xiphigorgia anceps	4
	Pseudoplexaura crassa	3
145.	Gorgonia flabellum	3
	acerosa	2
	Plexaurella dichotoma	4
146.	Gorgonia flabellum	2
	Xiphigorgia anceps	4
	Plexaura flexuosa	2
	Pseudoplexaura crassa	2
147.	Xiphigorgia anceps	3
	Plexaurella dichotoma	4
	Eunecia rousseaui	2
	crassa	4
148.	Gorgonia citrina	4
	Xiphigorgia anceps	2
	Pseudoplexaura crassa	1
	Eunecia crassa	2
149.	Gorgonia flabellum	1
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	2
150.	Plexaura flexuosa	2
	homomalla	1
	Pseudoplexaura crassa	1
	Plexaurella dichotoma	2

TABLE 11.—*Details of counts along line No. 2 (see page 350 and map).*

1.	Plexaura flexuosa	4
2.	Gorgonia flabellum	2
	acerosa	1
	Plexaura flexuosa	2
	Plexaurella dichotoma	8
	Eunecia crassa	5
3.	Gorgonia flabellum	3
	Xiphigorgia anceps	2
	Gorgonia citrina	4
	Pseudoplexaura crassa	4
	Plexaurella dichotoma	5
4.	Plexaura flexuosa	5
	homomalla	1
	Pseudoplexaura crassa	3
	Eunecia rousseaui	3
	crassa	7
5.	Pseudoplexaura crassa	3
	Plexaurella dichotoma	7
	Briarem asbestum	4
6.	Gorgonia flabellum	2
	acerosa	2
	Xiphigorgia anceps	3
	Plexaura flexuosa	6
	Eunecia crassa	3
7.	Gorgonia citrina	6
	Plexaurella dichotoma	5
	Briareum asbestum	3
8.	Gorgonia flabellum	4
	acerosa	2
	Pseudoplexaura crassa	2
	Eunecia rousseaui	2
	crassa	3
9.	Gorgonia acerosa	3
	Eunecia crassa	5
	Briareum asbestum	2
10.	Plexaura flexuosa	5
	Pseudoplexaura crassa	3
	Plexaurella dichotoma	5
	Eunecia rousseaui	2
11.	Gorgonia citrina	5
	Xiphigorgia anceps	2
	Plexaurella dichotoma	5
	Eunecia crassa	3
12.	Barren.	
13.	Gorgonia flabellum	3
	Eunecia crassa	7
14.	Gorgonia acerosa	2
	Plexaura flexuosa	3
	Plexaurella dichotoma	7
	Pseudoplexaura crassa	3
15.	Barren.	
16.	Pseudoplexaura crassa	3
	Plexaurella dichotoma	9
17.	Gorgonia flabellum	2
	citrina	5
	Xiphigorgia anceps	2
18.	Gorgonia flabellum	2
	Plexaura flexuosa	2
	Pseudoplexaura crassa	3
	Eunecia crassa	4
19.	Plexaura homomalla	1
	Plexaurella dichotoma	7
	Eunecia rousseaui	1
	Briareum asbestum	2
20.	Gorgonia acerosa	1
	Xiphigorgia anceps	2
	Eunecia crassa	4
21.	Gorgonia flabellum	2
	citrina	3
	Plexaura flexuosa	2
	Pseudoplexaura crassa	1
	Plexaurella dichotoma	4
22.	Barren.	
23.	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Eunecia rousseaui	2
	Briareum asbestum	2
24.	Gorgonia flabellum	2
	Xiphigorgia anceps	3
	Plexaurella dichotoma	5
	Eunecia crassa	4
25.	Plexaura flexuosa	3
	Pseudoplexaura crassa	3
	Briareum asbestum	2
26.	Gorgonia acerosa	2
	citrina	5
	Eunecia crassa	4
27.	Xiphigorgia anceps	4
	Plexaurella dichotoma	7
28.	Gorgonia flabellum	2
	acerosa	3
	Plexaura flexuosa	3
	Plexaurella dichotoma	6
29.	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
	Briareum asbestum	1
30.	Gorgonia acerosa	2

TABLE 12.—*Details of counts along line No. 3 (see page 350 and map).*

1.	Gorgonia flabellum	2
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	4
2.	Gorgonia citrina	3
	Xiphigorgia anceps	2
	Plexaura flexuosa	4
	Eunecia crassa	4
3.	Plexaura flexuosa	4
	Pseudoplexaura crassa	2
	Eunecia rousseaui	1
4.	Gorgonia acerosa	2
	Plexaurella dichotoma	5
	Briareum asbestum	1
5.	Gorgonia flabellum	3
	Plexaura flexuosa	4
6.	Gorgonia flabellum	1
	Xiphigorgia anceps	3
	Eunecia crassa	4
7.	Barren.	
8.	Plexaura flexuosa	3
	Pseudoplexaura crassa	1
	Plexaurella dichotoma	5
9.	Plexaurella dichotoma	5
	Pseudoplexaura crassa	3
10.	Gorgonia acerosa	3
	Eunecia rousseaui	2
	crassa	4
11.	Gorgonia flabellum	2
	acerosa	1
	Pseudoplexaura crassa	3
12.	Gorgonia flabellum	2
	citrina	5
	Xiphigorgia anceps	4
13.	Plexaura flexuosa	4
	Pseudoplexaura crassa	3
14.	Plexaura flexuosa	4
	Pseudoplexaura crassa	2
	Briareum asbestum	1
15.	Gorgonia flabellum	3
	acerosa	2
	Plexaurella dichotoma	4
16.	Gorgonia flabellum	3
	Xiphigorgia anceps	2
	Eunecia crassa	4
17.	Gorgonia acerosa	2
18.	Plexaura flexuosa	5
	Plexaurella dichotoma	3
19.	Gorgonia flabellum	2
	acerosa	2
	Xiphigorgia anceps	1
	Pseudoplexaura crassa	1
20.	Gorgonia flabellum	2
	Plexaura flexuosa	3
	Pseudoplexaura crassa	1
	Plexaurella dichotoma	3
	Briareum asbestum	1

TABLE 13.—*Details of counts along line No. 4 (see page 350 and map).*

No.	Species	Count
1.	Gorgonia flabellum	2
	acerosa	2
	Xiphigorgia anceps	3
	Plexaura flexuosa	3
	Pseudoplexaura crassa	1
2.	Gorgonia flabellum	5
	citrina	7
	Plexaura flexuosa	4
	Plexaurella dichotoma	5
3.	Plexaura flexuosa	4
	Pseudoplexaura crassa	2
	Plexaurella dichotoma	7
	sp	2
4.	Gorgonia flabellum	5
	acerosa	3
5.	Gorgonia flabellum	3
	citrina	6
	Plexaura flexuosa	4
	homomalla	1
	Plexaurella sp	2
6.	Gorgonia flabellum	2
	acerosa	3
	Xiphigorgia anceps	5
	Plexaura flexuosa	5
	Pseudoplexaura crassa	3
7.	Barren.	
8.	Plexaura flexuosa	8
	Pseudoplexaura crassa	4
	Plexaurella dichotoma	3
9.	Gorgonia flabellum	4
	citrina	6
	Xiphigorgia anceps	3
	Plexaura flexuosa	2
10.	Gorgonia acerosa	9
	Pseudoplexaura crassa	3
11.	Gorgonia flabellum	7
	Plexaura flexuosa	6
	Plexaurella sp	3
12.	Xiphigorgia anceps	4
	Plexaura flexuosa	5
	Eunecia rousseaui	3
	crassa	5
13.	Gorgonia flabellum	5
	acerosa	4
	Plexaura homomalla	1
	Pseudoplexaura crassa	3
14.	Gorgonia acerosa	8
	Plexaura flexuosa	7
	Eunecia crassa	4
15.	Gorgonia flabellum	5
	Xiphigorgia anceps	3
	Plexaura homomalla	2
	Pseudoplexaura crassa	3
16.	Plexaura flexuosa	5
	homomalla	3
	Plexaurella dichotoma	6
	sp	3
17.	Gorgonia flabellum	5
	citrina	7
	acerosa	4
	Plexaura flexuosa	5
18.	Gorgonia acerosa	7
	Pseudoplexaura crassa	4
	Plexaurella dichotoma	6
19.	Barren.	
20.	Gorgonia acerosa	7
	Xiphigorgia anceps	5
21.	Barren.	
22.	Gorgonia flabellum	7
	citrina	10
	Plexaura flexuosa	8
	Pseudoplexaura crassa	4
23.	Gorgonia acerosa	5
	Xiphigorgia anceps	3
	Plexaurella dichotoma	6
	sp	2
	Eunecia rousseaui	1
	crassa	4
24.	Gorgonia flabellum	5
	acerosa	2
	Plexaura flexuosa	4
25.	Gorgonia flabellum	1
	citrina	5
	Plexaura flexuosa	6
	Pseudoplexaura crassa	3
26.	Gorgonia acerosa	1
	Xiphigorgia anceps	2
	Plexaurella dichotoma	4
	Eunecia crassa	4
27.	Gorgonia citrina	3
	Plexaura flexuosa	2
	Plexaurella sp	2
28.	Gorgonia flabellum	4
	acerosa	6
	Pseudoplexaura crassa	3
	Eunecia crassa	4
29.	Gorgonia acerosa	1
	Xiphigorgia anceps	2
	Plexaurella dichotoma	4
30.	Gorgonia citrina	5
	Plexaura flexuosa	7
	Pseudoplexaura crassa	2
31.	Barren.	
32.	Gorgonia flabellum	8
	acerosa	10
	Plexaura homomalla	1
33.	Gorgonia acerosa	13
	Xiphigorgia anceps	5
	Plexaurella sp	4
34.	Barren.	
35.	Do.	
36	Gorgonia flabellum	7
	citrina	11
	Plexaura flexuosa	6
	Pseudoplexaura crassa	4
37.	Barren.	
38.	Gorgonia flabellum	12
	acerosa	8
	Plexaura flexuosa	7
	Plexaurella dichotoma	3
39	Gorgonia acerosa	7
	citrina	9
	Xiphigorgia anceps	4
	Plexaura flexuosa	5
40.	Gorgonia flabellum	5
	acerosa	4
	Plexaura flexuosa	2
	Plexaurella dichotoma	1

TABLE 14.—*Details of counts along line No. 5 (see page 351 and map).*

No.	Species	Count
1.	Gorgonia acerosa	3
2.	Gorgonia acerosa	5
3.	Gorgonia acerosa	4
4.	Gorgonia acerosa	2
5.	Gorgonia acerosa	6
6.	Gorgonia acerosa	3
7.	Gorgonia acerosa	7
8.	Gorgonia acerosa	4
9.	Barren.	
10.	Gorgonia acerosa	7
11.	Gorgonia acerosa	3
12.	Gorgonia acerosa	3
13.	Gorgonia acerosa	5
14.	Gorgonia acerosa	3
15.	Gorgonia acerosa	5
16.	Gorgonia acerosa	
	Plexaura flexuosa	
	Pseudoplexaura crassa	
17.	Gorgonia flabellum	2
	acerosa	1
17.	Xiphigorgia anceps	2
	Plexaura flexuosa	3
	Pseudoplexaura crassa	2
18.	Plexaura homomalla	1
	Plexaurella dichotoma	6
	sp	1
	Eunecia crassa	3
19.	Barren	
20.	Gorgonia acerosa	1
	citrina	3
	Pseudoplexaura crassa	1
21.	Barren.	
22.	Gorgonia flabellum	2
	Plexaura flexuosa	3
	Plexaurella dichotoma	4
23.	Gorgonia acerosa	1
	Pseudoplexaura crassa	2
	Eunecia rousseaui	1
	crassa	5
24.	Barren.	
25.	Gorgonia flabellum	2
	Xiphigorgia anceps	2
	Plexaura flexuosa	4
	Briareum asbestum	1
26.	Plexaura flexuosa	3
	homomalla	1
	Plexaurella sp	2
	Eunecia crassa	3
27.	Gorgonia acerosa	1
	Pseudoplexaura crassa	2
	Eunecia rousseaui	3
28.	Barren.	
29.	Gorgonia flabellum	2
	Xiphigrogia anceps	4
	Pseudoplexaura crassa	2
	Eunecia crassa	4
30.	Gorgonia flabellum	2
	acerosa	1
	Plexaura flexuosa	4
	Plexaurella dichotoma	3

Map of the Tortugas Islands to show the location and character of the reefs from which the Gorgonians used in this study were collected. Drawn from U. S. Coast and Geodetic Survey Chart.

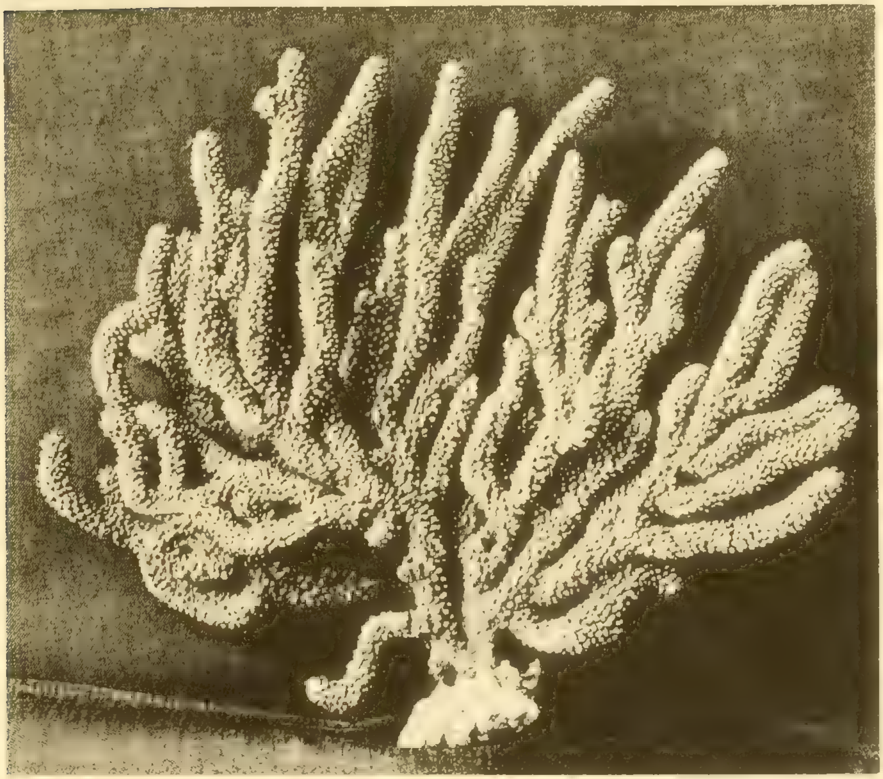

FIG. 1. Briareum asbestum. Three-fourths natural size.
FIG. 2. Eunecia rousseaui. One-half natural size.

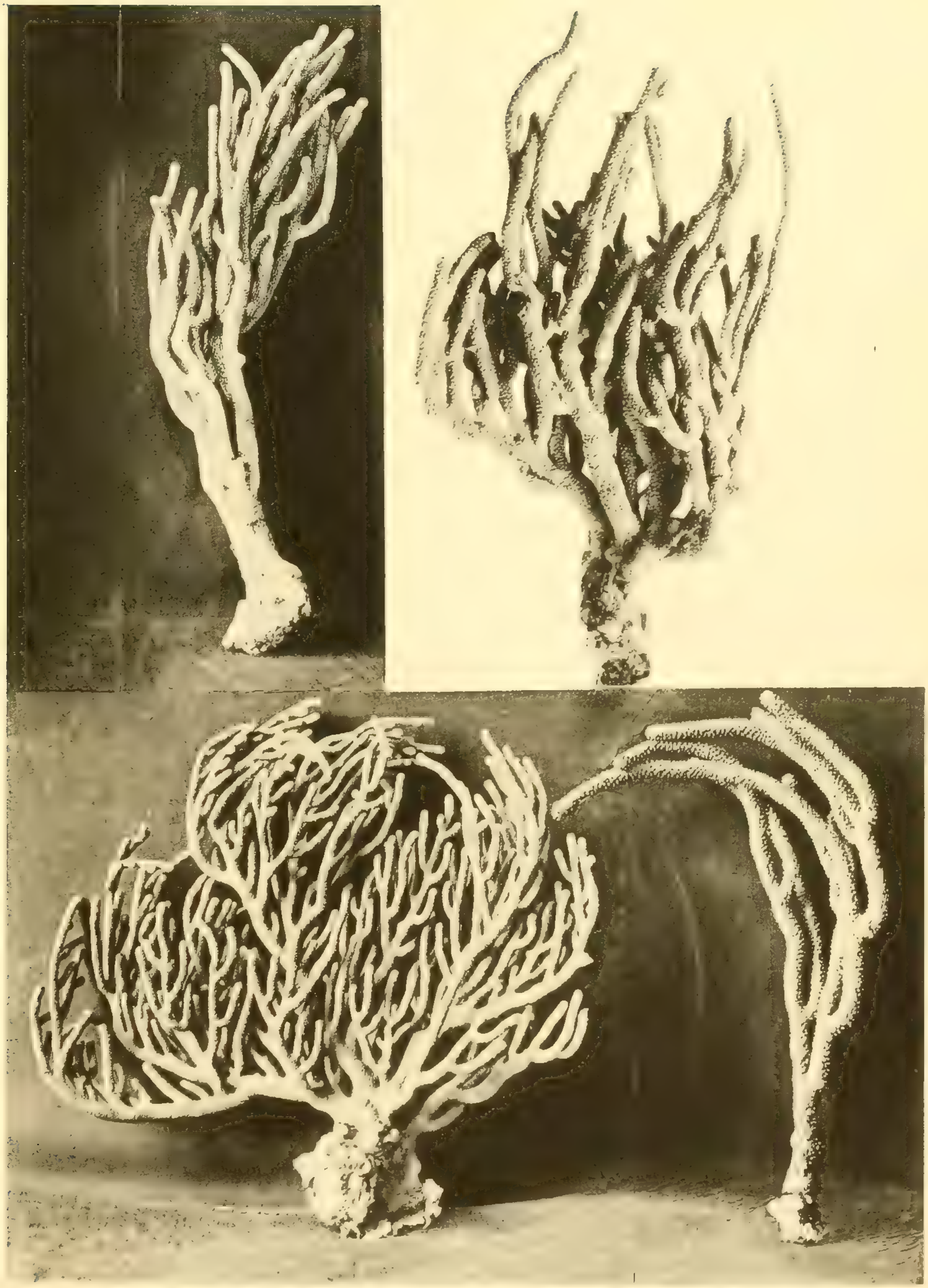

FIG. 3. Eunecia crassa. One-half natural size.
FIG. 4. Plexaura flexuosa. One-third natural size.
FIG. 5. Plexaura homomalla. One-fourth natural size.
FIG. 6. Pseudoplexaura crassa. One-third natural size.

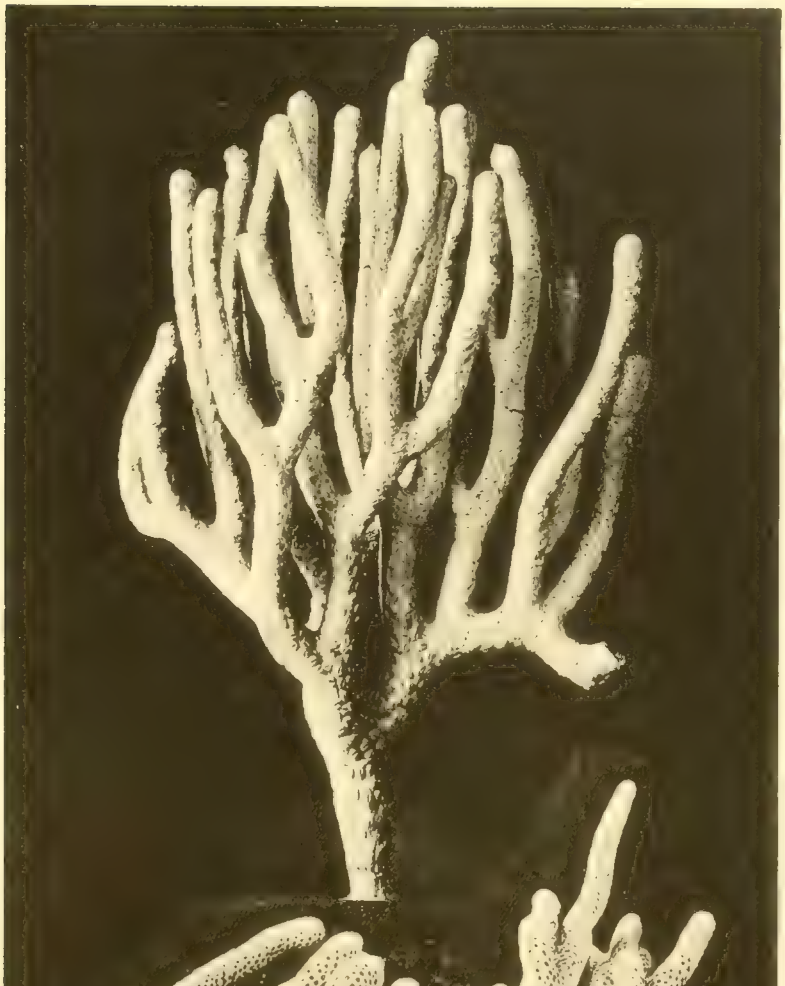

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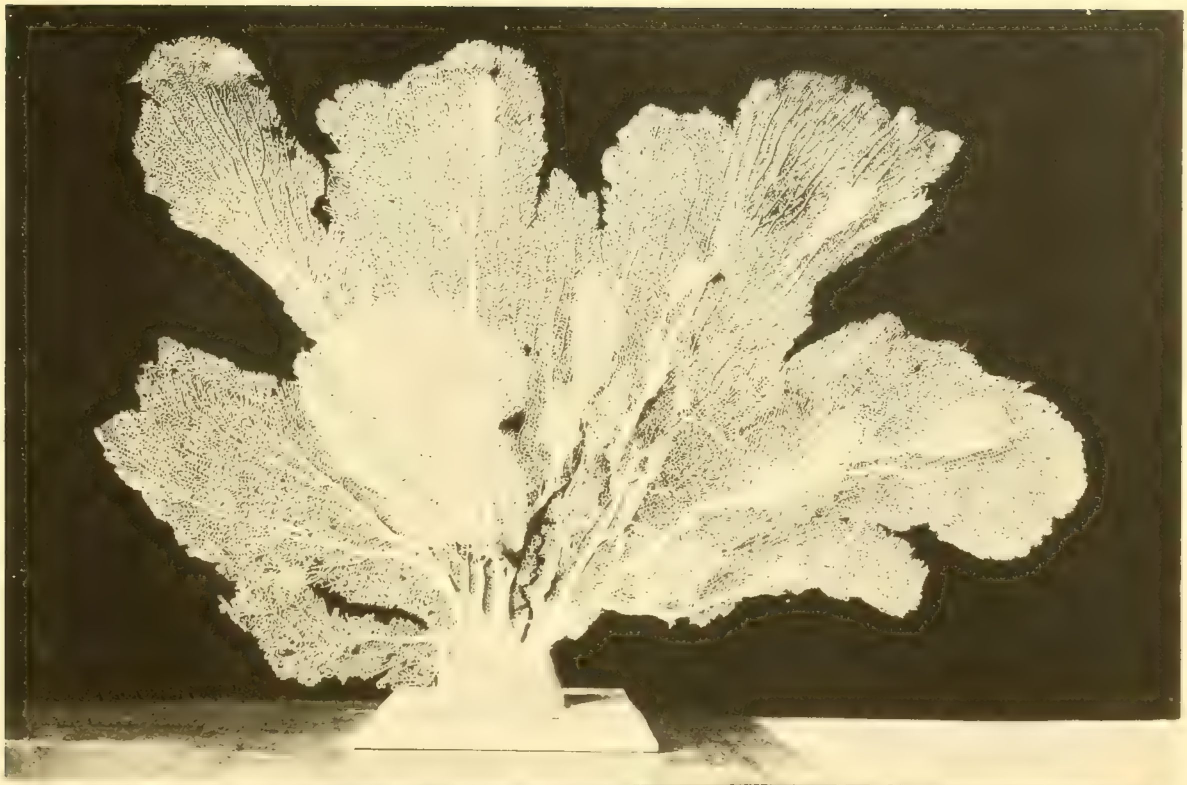
FIG. 7. Plexaurella dichotoma. One-half natural size.
FIG. 8. Plexaurella sp. One-half natural size.



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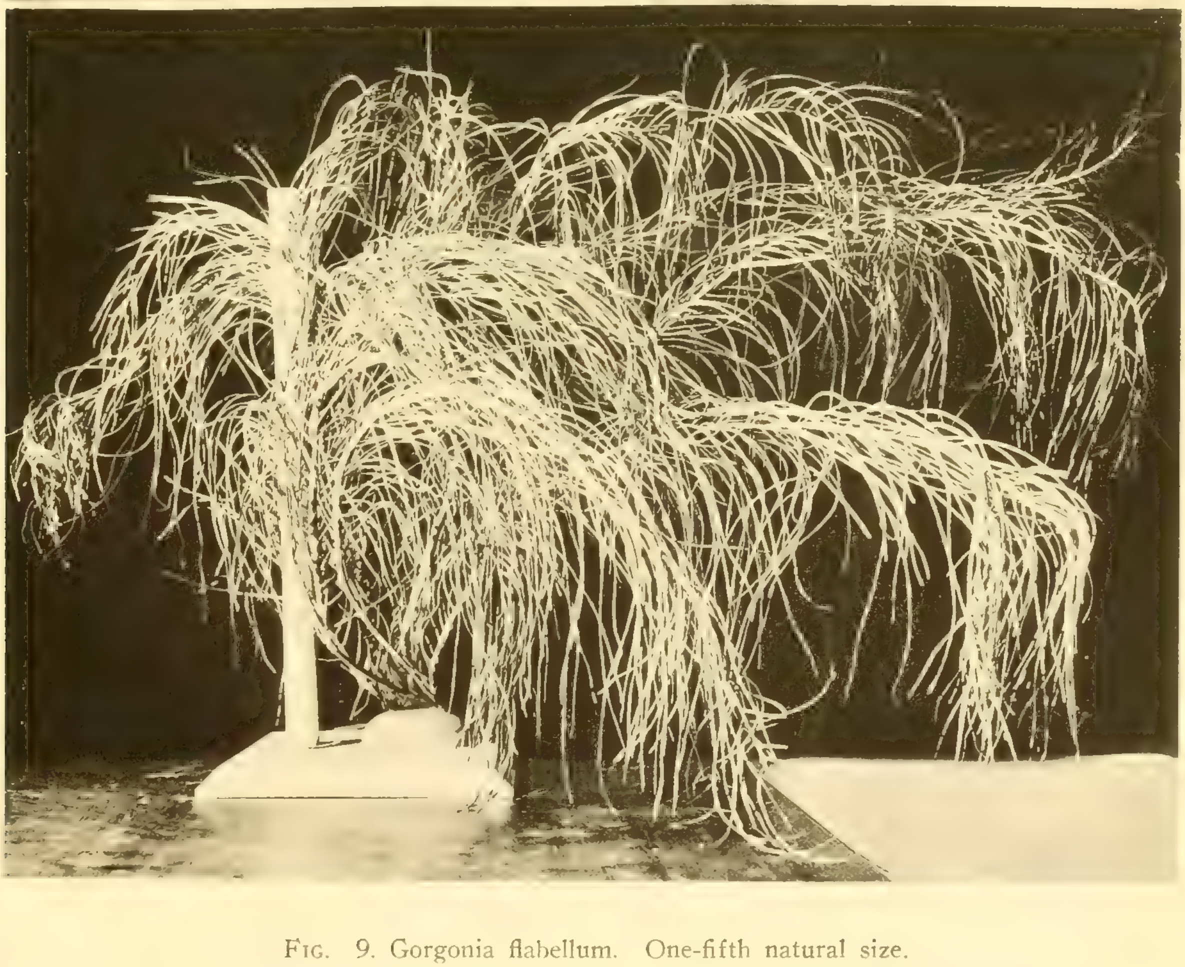

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FIG. 9. Gorgonia flabellum. One-fifth natural size.
FIG. 10. Gorgonia acerosa. One-fifth natural size.

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Fig. 11. Gorgonia citrina. Three-fourths natural size.
Fig. 12. Xiphigorgia anceps. One-third natural size.

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